Water and Energy

Conservation Alternatives for the North

Water and Sanitation Section
Department of Local Government
Government of the Northwest Territories

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WATER CONSERVATION ALTERNATIVES FOR THE NORTH

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FORWARD

This paper was originally presented at the symposium on "Utilities Delivery in Northern Regions" held in Edmonton, March 19-21, 1979. It is a summary of a comprehensive study conducted by the Northern Technology Unit, Environmental Protection Service and the Department of Local Government, Government of the Northwest Territories. The report, bearing the title, "Water and Energy Conservation Alternatives for the North", contains much more detailed information on northern utility systems, water use influences, costs and the economic analysis methodology. Additional detailed information is provided in nine appendices on rate structures and pricing policies; toilet, bathing, laundry, kitchen and miscellaneous water conservation alternatives; wastewater reuse; community systems; and consumer education. A final appendix contains a selected annotated bibliography to further assist the reader in choosing additional supplemental reference material. Supplier lists of water conservation equipment distributors and/or manufacturers are also provided in the appendices.

While this publication, as well as the more detailed version, is oriented towards northern use, it is hoped that the information presented will also be of value to anyone interested in water conservation and concomitant energy reduction in other than northern areas. If the reader requires further information, the more detailed version can be obtained by writing to either of the following addresses:

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ABSTRACT

Appropriate and cost-effective water conservation methods and technology can improve the levels of service and sanitation and the economics of providing water and sewage services in northern communities. This report reviews water use characteristics, pricing policies, plumbing codes, public acceptance, water conservation experiences, and the methods and technology to reduce water use and the concomitant energy requirements. Various administrative alternatives and water conservation technology for toilets, bathing, laundry, kitchen and households are analyzed with respect to appropriateness, public acceptance and cost-effectiveness. Economic analyses and water conservation strategies for both trucked and piped utility systems are presented.

Simple dual flush or dam attachments for conventional toilets, low-flow shower heads and flow control aerators for faucets are recommended to reduce water use in households with full conventional plumbing and serviced by piped water and sewer systems. In some cases low water use European toilets, front loading clothes washing machines, mixing faucets, insulated hot water lines and pressure reducers are economically attractive. These measures can reduce household water use by 38% to 55%.

For northern households with full conventional plumbing and serviced by trucked water delivery and sewage pumpout, it is recommended that existing conventional toilets be replaced with models that use 3 L or less per flush. Low-flow shower heads and flow control aerators are useful, and most trucked serviced households will find it economical to install a front loading clothes washing machine. Other alternatives include temperature control valves, hand-held shower units, mixing faucets, insulated hot water lines and circulating or return hot water systems. It is estimated that a household equipped with these cost-effective water conservation fixtures can reduce water requirements to 50 L/person•d.

Trucked systems are preferred in communities with limited water supplies, and very low water use fixtures such as recirculating toilets, self-closing hand-held shower units and spray faucets are recommended. If a central laundry facility is installed, household water requirements can be reduced to only 13 L/person•d.

A final recommendation is made for a water conservation demonstration project to monitor retrofit and new installations for both the piped and trucked systems.

RÉSUMÉ

Grâce à des méthodes et à des techniques de conservation de l'eau qui sont appropriées et efficaces sur le plan économique, on peut améliorer la qualité, la salubrité et les coûts des services de distribution d'eau et d'évacuation des eaux usées dans les collectivités nordiques. Dans ce rapport, on examine les caractéristiques d'utilisation de l'eau, les modalités de fixation des prix, les codes de plomberie et les méthodes et techniques de réduction de l'utilisation de l'eau, ainsi que les besoins connexes en énergie, la réaction du public et les expériences de conservation de l'eau. Diverses solutions administratives et techniques d'économie de l'eau pour le cabinet, le bain, la lessive, la cuisine et la maison sont analysées du point de vue de leur applicabilité, de leur acceptation par la population et de leur rapport efficacité/coût. Des analyses économiques et des stratégies de conservation de l'eau sont présentées pour les services publics fournis par camions et par canalisations.

L'installation de simples accessoires sur les cabinets ordinaires (double chasse ou vidage partiel), de pommes de douche à faible débit et de robinets équipés d'aérateurs limitant le débit, est recommandée dans les maisons dotées de toutes les installations ordinaires de plomberie et raccordées à des systèmes de distribution d'eau et d'évacuation des eaux usées par canalisations. Dans certains cas, l'utilisation de cabinets européens à faible consommation d'eau, de machines à laver à chargement par l'avant, de robinets mélangeurs, de canalisations d'eau chaude isolées et de détendeurs régulateurs, peut représenter une économie. Avec l'adoption de ces techniques, on peut réduire de 38 à 55% la consommation d'eau dans une maison.

Pour les maisons situées dans les régions nordiques, qui ont toutes les installations ordinaires de plomberie et où la distribution d'eau et l'évacuation des eaux usées se font par camions, on recommande de remplacer les cabinets classiques par des modèles utilisant 3 L d'eau ou moins par chasse et d'utiliser des pommes de douche à faible débit et des aérateurs limitant le débit. Dans la plupart des maisons, on suggère également d'installer une machine à laver à chargement par l'avant. L'installation de soupapes de réglage de la température, de douches-téléphones, de robinets mélangeurs, de canalisations d'eau chaude isolées et de systèmes de circulation et de retour de l'eau chaude, représente une autre solution. On estime qu'une maison dotée de tels dispositifs peut réduire à 50 L par personne ses besoins quotidiens en eau.

Dans les localités à approvisionnement limité en eau, on recommande un service d'approvisionnement et d'évacuation par camion et l'utilisation d'appareils à très faible consommation d'eau, comme les cabinets à recirculation, les douches-téléphones à fermeture automatique et les robinets à aspersion. Si on installe une laverie centrale, les besoins quotidiens en eau des maisons peuvent être réduits à 13 L par personne.

Finalement, on suggère une démonstration de la conservation de l'eau afin d'expliquer le fonctionnement des installations nouvelles ou modifiées, desservies par canalisations ou par camions.

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1 INTRODUCTION

The availability of water in sufficient quantity and acceptable quality is basic to human life. Although the North is generally endowed with abundant water, there are areas and communities that do not have sufficient year round potable water supplies. Even where water is readily available, the procurement and distribution of adequate potable water and the safe collection and disposal of sewage is difficult and expensive. The high cost of energy required for the heating and pumping of water can be a significant portion of both the utility operators' and consumers' costs associated with water use. The benefits of water conservation are generally greater in the North than elsewhere and the appropriate methods and cost-effective technology must be ascertained.

This report reviews water requirements and the methods and technology to reduce water use and the concomitant energy requirements. Various alternatives are examined with respect to appropriateness, public acceptance and cost-effectiveness. This report is a summary of a comprehensive study conducted by the Northern Technology Unit, Environmental Protection Service, with the Department of Local Government, Government of the Northwest Territories, as part of their ongoing efforts to provide cost-effective water and sanitation services in the north (Cameron and Armstrong, 1979). The initial concern was to reduce the costs for trucked water and sewage servicing but the study was expanded to include piped services. While the information presented is oriented towards households in the North, it is also applicable to other situations and locations.

2 WHY CONSERVE WATER?

Recent water shortages in many parts of the world and the "energy crisis" have publicized the need for reducing our water and energy demands. Less dramatic but perhaps more significant in the long run is the increased public concern for reducing waste and conserving our natural resources. From an economic perspective, water conservation and the concomitant energy savings makes "cents".

The desire for water conservation may be philosophical and/or economical. The potential benefits will vary with both the local conditions and utility system, and they may be accrued by the consumers, utility operators and agencies that provide direct or indirect subsidies, as well as the nation. This analysis of water conservation technology places major emphasis upon long-term cost-effectiveness and not periodic crisis situations or a philosophical conservation/environmental approach.

Water conservation will reduce the total and the peak hydraulic demands on the utility system; therefore, the required capacity of water and sewage facilities may be lower. Reducing demand may extend the life of existing facilities or, alternatively, the present facilities may be able to service more consumers. Capital expenditures for expansion may be deferred, or even obviated, and when expansion or replacement facilities are eventually needed the reduced capacity requirements will result in a lower cost for the new facilities. Piped systems typically have declining unit costs because of "economy of scale" and minimum capacity requirements, primarily for fire protection, but there are always some potential capital expenditure benefits from water conservation. Often these only become obvious when there is a crisis situation or an impending large capital expenditure. Variable operating costs, such as for preheating, pumping, chemicals and labour, are directly influenced by water demand.

Trucked systems typically have a relatively high and constant unit price, and the total cost of water delivery and sewage pump-out service is primarily dependent on water use. The economic benefits of reduced demand are evident and easily calculated. The efficient use of water is essential to make trucked systems practical and competitive with piped systems. Reduced demand within buildings provides greater reserve capacity for essential uses, which results in a more reliable truck system.

The consumer will benefit from reduced utility system costs through lower total water and sewer bills, even though the unit price may be higher in order to return the necessary revenue to the utility operators. The consumer will benefit from reduced

hot water consumption through lower energy bills and the convenience of seemingly increased capacity from existing hot water heaters.

Wastewater treatment facilities that are primarily hydraulically designed, such as winter retention lagoons, can be significantly influenced by water use. The performance and cost of other treatment and disposal methods may benefit from significant reductions in wastewater flows but they must be designed for the higher strength of the less dilute wastewater. In some cases the reduced pollution or "zero discharge" provided by some toilet and reuse systems may be necessary and/or economical.

At locations with limited water supplies the efficient use of water is imperative. There are some communities in the North that do not have an economical or practical water source during the winter and enough water storage capacity must be provided for the community demands during that period (Reid, 1977; Foster et al, 1977). In these locations restrictive water conservation measures and technology will be essential and economical.

3 WATER USE

It is necessary to determine how much water is consumed in households and for what purposes it is used before water conservation alternatives can be assessed. The representative data on water consumption in Table 1 indicates that there is no "average" residential consumption and the total use depends on many factors. Water is used in households through various water-using appliances and fixtures. The mean values of several studies which measured household water use patterns for piped and individually serviced houses are illustrated in Figure 1. Naturally, there can be significant variations within individual households. Water use studies have not been conducted for houses serviced by trucked systems but, given the same plumbing and fixtures, it is expected that the pattern would be similar.

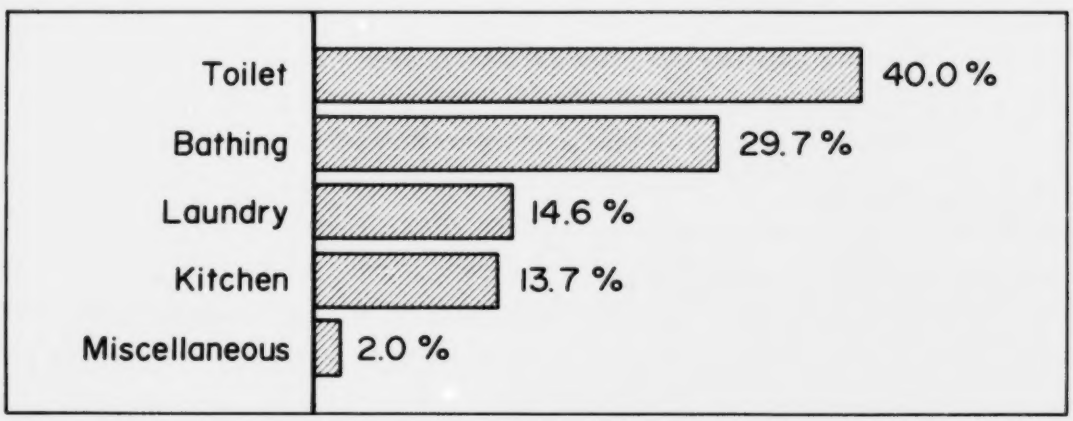


FIGURE 1 HOUSEHOLD WATER USE DISTRIBUTION

TABLE 1 WATER CONSUMPTION LITERATURE SUMMARY

CONSUMPTION L/person·d	COMMENTS	REFERENCE
240	1963-1965 residential, annual metered average, western U.S.A.	Howe & Linaweaver, 1967
167 68 - 261	average, 18 residential homes, Louisville, range	Anderson & Watson, 1967
263 171	1968 residential, unmetered average, Toronto 1968 residential, metered average, Toronto	Grima, 1972
114 - 189	range for residential	Wallman, 1972
330 1325 208	January residential, Phoenix, Arizona July residential, Phoenix, Arizona July residential, Baltimore, Maryland	Whitford, 1972
253 167	sewered households households connected to septic tanks	Cohen and Wallman, 1974
168 31 - 615 153 - 182	mean, 19 rural households range, 95% confidence interval	Ligman et al, 1974
169	average of 6 households	Bennett, 1975
161 154 - 168	average of 11 rural households 90% confidence interval	Siegrist et al, 1976
190 217 420 202 210 465	1972-73-74 residential, metered average, Edmonton 1972-73-74 residential, metered average, Calgary 1972-73-74 residential, unmetered average, Calgary 1975 residential, metered average, Edmonton 1975 residential, metered average, Calgary 1975 residential, unmetered average, Calgary	Gysi and Lamb, 1977*
236	1977 Edmonton, metered, 3.5 persons/house	Betker, 1977
625	1975, mean for 2780 municipalities in Canada	Environmental Protection Service, 1977
485	1973, Inuvik, serviced portion of community	Associated Engineering Services Ltd., 1973
1680 1135 - 2500	Whitehorse, residential with bleeders, average range	Stanley & Associates Engineering Ltd., 1974
530 - 6200	1973 survey, 20 Alaskan communities (high range use bleeders)	Hansen, 1975
430	1975, Yellowknife, total community	Environmental Protection Service, 1977
118 45 - 295 70 - 167	Yellowknife trucked households, 2.85 persons/house,* mean range 95% confidence interval	Cameron, 1977
9	no plumbing, N.W.T. communities	
243 160 - 410 200 - 286	mean, 200 - 1300 man camps range 95% confidence interval	Murphy et al, 1977
86	18 man camp washcar with vacuum toilet (kitchen wastes excluded)	Given and Chambers, 1976

*reported total household consumption values were divided by average 4 persons/house.

4 WATER USE INFLUENCES

Household water use depends on many factors, which include household plumbing, type of utility system, family size (i.e., number of occupants), socio-economic status, climate, rate structure, the price of water and plumbing codes.

In northern communities with individual haulage, or where water is delivered to houses with no plumbing, the consumption is only about 10 L/person•d. Such a low value is not conducive to proper hygiene and good health. To rectify this various government agencies have programs to improve community and household facilities. Water consumption increases dramatically in houses that are equipped with hot and cold running water and water-using fixtures and where an organized community utility system exists. Data from an area of Yellowknife, N.W.T. that is serviced by a trucked system indicates that a four-person household with full conventional plumbing uses approximately 95 L/person•d. This relatively low water use for households serviced by trucks can be attributed to the lower water pressure obtained from the individual pressure pumps and a general consciousness of a limited quantity of water available within the household water tank. Water use habits are modified to reduce waste and leakage and some water conservation methods are used.

Households on piped systems consume large volumes of water, partly because of the seemingly unlimited quantity of water available. Indoor water use for a household of four is typically 225 L/person•d. but, where bleeding is used to maintain a flow and prevent freezing of water and sewer lines, the consumption can exceed 2500 L/person•d. With rising energy and utility system costs, new systems are usually designed so that bleeding is unnecessary. Measures to reduce or eliminate water bleeding in existing utility systems are presently being investigated (Armstrong and Given, 1979). Another typically northern problem is the overheating of water mains that are in utilidors with central heating lines. A considerable volume of water is wasted during attempts to obtain a cool glass of water.

Gravity sewer systems require minimum velocities to prevent solids deposition. Toilets that use less water but flush rapidly or in a slug can maintain a high discharge rate and should perform adequately when a 100-mm diameter house connection at a standard 2% slope is used (Cole, 1975; Konen and DeYoung, 1975). With non-gravity sewer systems, small-diameter pipes and very low-water use toilets can be used. In particular, a special 1.5-L flush toilet is available for use with vacuum sewer systems.

Total water demand increases with the number of persons residing in the dwelling but the per person consumption decreases. The decrease is because of the relatively fixed quantities of water used to perform certain household tasks, regardless of the number of occupants. The socio-economic status is an indirect measure of water use and is indicative of the water-using fixtures and operations within the household.

Outdoor water uses are influenced by the climate; in northern regions, the outdoor water use may be relatively low because of the short summers and few lawns.

The primary purpose of a rate structure and price is to recover revenue. The water demand, particularly outdoor use, is influenced by the pricing policy and the price can be used to manipulate water demand (Howe and Linaweaver, 1967; Grima, 1972). The various rate structures that have been used include: flat rate (constant price per litre); declining block rate (decreasing price per litre); increasing block rate (increasing price per litre); demand and peak load rates; and seasonal pricing. Without metering, the same flat rate is charged regardless of consumption. A flat rate provides no incentive, economic or otherwise, for consumers to reduce water use and they typically use 30% to 50% more water than metered customers. With all of the other rate structures, water consumption can be influenced to some degree and the cost of water and sewer services can be equitably distributed. Using a detailed economic model Chan et al (1976) showed that, with respect to water demand, the rate structure itself was only significant to the extent that it established the marginal price. At equal marginal prices the demand was the same regardless of the rate structure. With the notable exception of an unmetered flat rate, any unit price scheme can equitably return adequate revenue while facilitating water conservation and encouraging efficiency, providing the unit price reflects the actual cost for that service.

The rate structure and price should reflect the actual long-term marginal cost of the utility system. Unfortunately it is impractical to precisely determine this cost, particularly for piped systems, and administrative practicalities and subsidies can distort or even dictate the pricing scheme and the price. For heavily subsidized utility systems and in small communities it is tempting to charge a flat rate to reduce administrative complexities. Given the social, political and technical constraints, it is no wonder that "the procedures for designing water rates have generally been on a trial and error assumption applied to the sales records of the particular community" (American Water Works Association, 1954). Some compromise and inefficiency must be expected but this

should not detract from the goal of recovering the total long-term cost of providing the last unit of water demanded.

Direct and indirect subsidies of utility systems and energy costs are particularly extensive in the north. Subsidies may facilitate the achievement of social, political, administrative, economic or public health goals. However, they must be examined to ensure that in attaining these goals they do not induce undue inefficiencies into the utility system. Subsidies that reduce or even eliminate the charge for services tend to distort the demand and this can result in excessive water use, high utility system costs, and the need for further subsidies. Utility system subsidies may include: capital and/or operating grants or loans for installation and/or operation of the utility system; or price subsidies to consumers. Where these subsidies are extensive, the agencies providing the subsidies will be the main beneficiaries of reduced water and energy demands. In other cases, various costs and benefits associated with water conservation are realized by the consumers and the agencies. All agencies that provide subsidies have a responsibility to ensure equity and efficiency within the utility system and cost-effectiveness in the expenditure of public funds. This may be achieved by charging consumers the full economic rate (marginal price) for water consumption that is above a reasonable quantity. In some cases, subsidies for the purchase and installation of water conservation devices may be appropriate, equitable, and more economical than utility system subsidies. Similar national programs have been initiated to assist homeowners and industry to reduce heat loss and energy demand.

Plumbing codes and guidelines are usually established to protect the safety and health of the consumer and to establish minimum standards for materials and operation. Codes and guidelines have also been used to promote the use of water conservation technology to reduce water demands. The most common provisions establish a maximum flush volume for tank-type toilets of 13 L (3.5 US gallons), maximum flow rates of 11 to 13 L/min (3.0 to 3.5 US gal/min) for shower heads, and 7.6 to 15 L/min (2.0 to 4.0 US gal/min) for other faucets. Regardless of the use of plumbing codes to reduce water demand, it appears desirable to revise existing codes so they at least permit the use of water conservation devices where they are warranted on the basis of economics, sanitation or other considerations. Plumbing codes should encourage efficiency and not unjustifiably impede water conservation as do some existing standards.

5 WATER CONSERVATION

There are several methods of reducing water demand, including; administrative practices, educational campaigns and water conservation technology. When encouraging or implementing water conservation measures, the cultural attitudes and the users' personal biases must always be considered. Utility operators or subsidizing agencies interested in reducing water demand should initiate a public information and education campaign that involves the consumers. Changes in wasteful attitudes and behavioral practices, combined with knowledge of simple water conservation hints and an awareness of the benefits of water conservation, can in themselves produce a significant reduction in total water demand.

A recent example of a public educational effort is the drought management practices that were instituted in Marin County, California to deal with their two-year long water shortage (Nelson, 1977). In 1976, media coverage and a public information campaign about the problem and the necessity for reducing consumption enabled the Marin Municipal Water District to successfully cut water demand by 25 to 30% of the average annual demand. In 1977, to further reduce water demand, county water officials gave each customer an allotment of water, based on the number of people in the household. To maintain the quotas implemented, stiff new water rates were imposed. The basic rate was doubled, anyone who used up to twice the quota paid more than eight times the old rate, and usage beyond that cost 40 times the pre-drought rate. To help their customers meet these quotas, the district distributed water saving tips and other instructions plus offered free water saving kits, which included low-flow shower inserts and bottles to put into toilet tanks. As a result, Marin County residents reduced their water consumption by 65% and there were few occasions when consumers exceeded their quota. When the drought ended and restrictions were relaxed, according to Consumer Reports (May, 1978), water consumption was still running 45% below pre-drought levels. While this campaign was in response to a crisis situation, it does point out the benefits of consumer education, and the need for consumer acceptance of water conservation measures or practices.

6 WATER CONSERVATION TECHNOLOGY

Water requirements can be conveniently reduced by the use of water conservation technology. Tables 2 to 6, covering the categories of toilet, bathing, laundry and miscellaneous water use alternatives, provide a summary of the various water conservation devices. These tables provide a representative and as complete as practical outline of the alternatives and products. For any given device there may be many variations and several models available from manufacturers. An unbiased testing program was not carried out; therefore, in many cases the operation and performance data is based on published literature, manufacturers' information and personal experience. Existing plumbing codes may restrict the use of some water conservation alternatives even though they perform adequately. Not all devices are technically viable or appropriate for particular situations and, of course, user acceptance must be considered.

Familiarity with water conservation methods and devices will improve their acceptance and increase their application. This is particularly true for new technology and foreign devices that may be rejected without trial even when they provide an adequate or even superior level of service or convenience.

Consumers and utility agencies must be made aware of the strict economics of various functionally adequate water conservation alternatives. Intangibles such as social desirability, aesthetics, user preferences and convenience, applicability of technology, and numerous other pros and cons associated with each alternative have been left out of the economic analysis to provide unbiased economic conclusions. These other factors can be considered subjectively in conjunction with the strict economics to decide a course of action. It is important to note that the lowest cost alternative is not necessarily the "best" choice, rather it is simply the lowest cost given the assumptions in the analysis.

There are practical and technical limitations to a comparison and economic selection among alternatives. All capital, installation, and operation and maintenance (O&M) costs associated with an alternative must be discounted to obtain their present value. Since these costs depend on the unit costs for water, sewerage and energy, the number of users or volume used, and the O&M costs, each new and retrofit situation will be different. The marginal unit costs, net of any subsidies, should be used to arrive at cost, but these are often difficult or impractical to obtain.

The economics are specific to each utility system and location. A precise but very complex analysis would be based upon the change in total utility svstem and

TABLE 2 TOILET MODIFICATION ALTERNATIVES

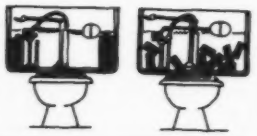
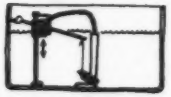
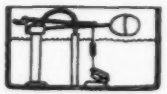
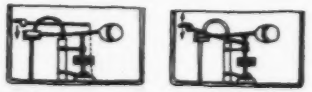
	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Bricks or plastic bottles 	Bricks or plastic bottles filled with water and weighted with small stones or completely filled with sand or gravel are inserted into the toilet tank. For each flush they displace and, therefore, save water equal to their volume.	Inexpensive, easily installed homemade devices usually consisting of discarded household items. If inadequate flushing results, plastic bottles can be cut reducing the size until the toilet flushes satisfactorily.	Bricks deteriorate in water and particles will clog water jets and lodge under the flush valve causing a continuous leak. They can also crack the tank if dropped or fall over, and multiple bricks will inhibit the flow of water around them. Bricks are not recommended. Plastic bottles can shift and interfere with the flushing mechanism and if filled with sand and not properly sealed, escaping sand can lodge under the flush valve resulting in a continuous leak.	None	Depends on size. Two bricks or two plastic bottles will save approximately 2 litres or about 10% per flush.	Low to none for homemade.	None
Improved float assemblies 	Replaces existing conventional float ball and fill valves, allowing water levels to be lowered and adjusted to use exactly the minimum amount of water necessary for efficient flushing.	Improves flushing efficiency and some will facilitate the detection of leaks. Potentially more durable than conventional replacement equipment due to less wear. Valve on leak signaling type is always in fully open or closed position, therefore, is quieter than slow closing conventional ballcocks.	Water savings are essentially limited to the elimination of leaks. Slightly higher cost than conventional replacement equipment.	Connects to toilet water line.	Depends on existing mechanism, therefore, savings can vary from none to significant. Very little data is available on how much water is lost due to leakage.	$6. - $10.	None
Dams	Plastic or metal wall is inserted into toilet tank in a verticle position and sealed against the sides and bottom of tank. Some types encircle the flush valve outlet, but all prevent the lower portion of water from draining out of the tank when the toilet is flushed.	Easy to install and will reduce water usage more than homemade devices. Will not interfere with static head or flush mechanism. Types made of metal and rubber are potentially more durable than those made of plastic.	Some types are not adjustable to allow only the minimum amount of water for efficient flushing to be released. Due to the age and design of some toilets they may not give an adequate flush.	None	Saves approximately 35% or about 7 litres per flush.	$4. - $8.	None
Weights 	Attached to the ball-chain or rod. After the desired amount of water is flushed the flush handle is released, and the weight immediately forces the stopper back into the flush valve seat, and flow stops.	Nearly as effective as dams in reducing water consumption and can be used in conjunction with dams to maximize savings. Can be homemade.	Negates the normal operation of the toilet flush mechanism and user must hold down handle for both solid and liquid waste until the desired quantity of water has been released. Commercial types have no advantage over homemade varieties.	None	Saves an average of approximately 30% or about 6 litres per flush.	$.80 - $8. None for homemade.	None
Dual - flush mechanisms 	Single action type can be a counterweight, floating cylinder or air bleeder mechanism which manipulates the flush valve stopper. When toilet is flushed normally, only a portion of flush water is released. For a full tank flush, the flush handle is held down. Double action types replace existing flush valve assembly. The flush handle moves in one direction for low volume flush (liquid wastes) and in the opposite direction for full flush (solid wastes).	Allow for user choice in flush quantities. Can be used in conjuction with dams.	Single action types require handle to be held for full tank volume flush. Air bleed types could become clogged with water deposits or dirt. The double action flush mechanism is difficult to install and since it is not adjustable, it may not give an adequate flush in all toilets.	None	Saves approximately 50% for low volume flush resulting in an average total saving of approximately 30% or 6 litres per flush.	$3. - $15.	None
Replacement tanks	Mounts on existing toilet bowl replacing the whole reservoir tank with a pressure tank cartridge and cover. Water entering the empty tank compresses the air inside, stopping when water and air pressure are equal. When toilet is flushed, compressed air and gravity force water into the bowl.	Uses about half the water used by a conventional toilet tank.	Expensive and more difficult to install than other devices. Somewhat noisy at high pressure and may not work adequately on systems with water pressure less than 240 kPa.	Mounts on standard toilet bowl and must be connected to water line.	Uses approximately 9.5 to 11.5 litres per flush, therefore, saves approximately 50%.	$65. - $95.	None

TABLE 3 TOILET ALTERNATIVES

	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Outhouse	Wastes biodegrade in pit and seep into soil. Pit gradually fills and outhouse must be moved.	Easy, inexpensive, no pipes, no water required, no moving parts.	Unpleasant odors, cold in winter, inconvenience of access, can contaminate water sources. Not applicable for use in developed communities or in areas with permafrost. Must be periodically moved to new site.	None	None	$0-$150	$0
Bucket	Wastes drop directly into bucket with deodorizing chemical or into plastic "honeybag." Bucket is dumped and recharged periodically or "honeybag" is removed for pick-up and replaced with fresh bag.	Inexpensive, simple, no water required, no moving parts.	Little more than an indoor outhouse. Removal of wastes from the building and the collection and disposal is often unsanitary. Collection should be 5 times per week.	Vent only.	None	$25-$100	Varies, but is low. Some require chemicals and/or plastic bag inserts (5c/bag).
Conventional	Wastes are syphoned through a trap by a sudden rush of water from the tank reservoir.	Sanitary, odorless, relatively easy to repair and inexpensive to buy.	Uses large quantities of water to transport small quantities of wastes. Ultimate disposal of sewage is a problem. Requires pressure water supply and piped gravity sewage collection system.	9.5mm water 75mm waste	13-30 litres/flush avg. 20 litres/flush	$60-$240 Some as high as $500	Depends on cost of water; family of four would use approximately 400 litres per day for flushing
Shallow trap	Same as above, except has a shallower trap and smaller reservoir tank.	Same as above, except toilet water use is approximately 33% less than conventional.	Same as above except uses less water.	same as above	13-16 litres/flush avg. 14.5 litres/flush	$80-$200	Same as above except family of four would use approximately 290 litres per day for flushing.
European 6L	Wastes are syphoned through a trap by a sudden rush of water. Has shallow trap and smaller reservoir tank than conventional. Models with 9 litre flush available.	Sanitary, odorless, toilet water use is approximately 70% less than conventional.	Sewer pipe connection is centred at back of toilet therefore may present retrofit problems. Performance not as good as conventional North American toilets, particularly for non-human waste materials.	9.5mm water 75mm waste	6 litres/flush	$170-$225	Depends on cost of water; family of four would use approximately 120 litres per day for flushing.
European 3L	Same as above with smaller trap and water mirror.	Same as above, except toilet water use is approximately 85% less than conventional.	Same as above but connection must be to a ground tank, not a piped sewage collection system. Several recommendations for installation with respect to sewer pipe size, slope and maximum distance. These may inhibit use as retrofit.	same as above	3 litres/flush	$220	Same as above except family of four would use approximately 60 litres per day for flushing.
Flush valve	Handle releases high velocity water injection producing swirl effect to syphon wastes through a trap.	Eliminates need for bulky reservoir tank and generally have a shorter pre-fixed cycle and quicker recovery time. Toilet bowl is well cleaned by flushing action.	Depend on water line pressures and will be affected by pressure changes due to use of other fixtures. Requires 25 mm water service line, therefore, is not applicable for household use.	25mm water 75mm waste	8.5-16 litres/flush	$100-$175	Depends on cost of water; family of four would use approximately 170-320 litres per day for flushing.
Air pressure	Wastes and flush water drop from bowl into a secondary chamber where an air charge is induced to pressurize and eject water and waste materials into discharge line.	Uses little water and will retrofit into conventional plumbing system. Same air compressor can be used on multiple toilet installation. Does not have reservoir tank.	Requires air compressor or compressed air bottle and operation is relatively complex. High capital cost plus power requirement for air compressor or recharging of air bottle.	9.5mm water 75mm waste compressed air at 410 kPa or electricity for compressor.	2 litres/flush	Vitreous China $600-$675 Stainless Steel $800-$875 Air Compressor $400	Cost of water and electricity. Family of four would use approximately 40 litres per day for flushing and 15 kW-h per year to run compressor.

TABLE 3 TOILET ALTERNATIVES (continued)

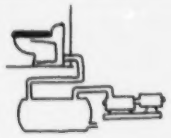
	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Vacuum 	Vacuum toilet connected to special valve mechanism and discharge piping. Utilizes an air pressure differential created by partially evacuating the air from the pipe network to transport slugs of wastewater through small diameter piping to central collection vacuum tank.	Uses little water and toilet does not have reservoir tank. Collection system uses small diameter plastic pipe which can be installed relatively independent of grade. Vacuum mains can be laid in same trench as watermains and have less heat loss due to lower volumes of fluid transported. Can be connected to multiple units within the same building or community.	Relatively complex operation and high capital cost. System requires back-up pumps and power. Installation requires qualified personnel.	9.5mm water 38mm waste electricity at collection tank for vacuum pump	1 litre flush	Individual building approx. $3500 Community systems vary.	Cost of water and electricity to run vacuum pump.
Mechanical seal	Pedal or handle opens valve in bottom of bowl and actuates swirl of fresh water to rinse bowl. Also, portable models with detachable holding tank for dumping of waste.	Fresh water flush but very low water use. No chemicals or recirculating. Can be used as portable unit with holding tank.	Sewer lines will clog due to low volume flush, therefore should only be used when there is a relatively straight drop into a holding tank. Portable unit must be dumped and recharged.	Varies from none to 9.5 mm water and 75 mm waste to holding tank.	.5 litres/flush	$75-$175	Depends on cost of water. Family of four would use about 10 litres per day for flushing. Portable model requires deodorizing chemical.
Marine	Hand or electric pump brings water into bowl. Valve is turned, same pump ejects wastes. Can pump wastes uphill.	Relatively low water usage. Can pump its waste uphill. Pumps its own water and could be used as a recirculating toilet.	Clogs relatively easily. Relatively complicated to use. Power consumption for electric models.	19 mm water 38 mm waste 120V or 12V for electric models	1 litre/flush, electricity for some models	$100-$400	Depends on cost of water and nominal power for electric models.
Recirculating	Hand and/or electric pump swirls filtered, chemically treated wastewater from holding chamber to flush and rinse bowl. When full, unit must be dumped and recharged with chemical and water. Portable or fixed models available.	Uses very little water. Fixed units can be used with conventional plumbing; usually discharge to holding tank.	Relatively complex and some larger commercial models expensive to buy. Requires dumping and recharging with chemicals every five days for family of four.	Varies from no hookups to 120V or 12V; 9.5 mm water; and/or 75 mm waste to holding tank or sewer.	0.2 litres fresh water/flush, electricity for some models	$90 (portable) $350 (fixed) Up to $3000 for public washroom system.	Depends on cost of water and nominal power for 12V or electric models. Family of four would use 4 litres per day. Chemical cost approx. $.50 per charge or $0.10 per day for a family of four.
Packaging	Wastes drop into plastic lined bowl. The continuous tube of plastic is drawn down through the bowl and is heat sealed to form a series of "sausages." Plastic bag under toilet collects "sausages" which must be periodically removed.	Handling of waste is improved. Odors and breakage of bags is minimized by isolating small quantities of waste in separate "sausages."	Expensive to buy and use. Requires plastic liners, collection bags and electricity. Collection and ultimate disposal of bags must be organized and can create problems.	120V electricity	Electricity, no water	$500-$1000	Manufacturer claims electrical consumption is 1 kW-h per 3400 uses. Costs for regular changing of collection bags and liners.
Freezing	Wastes drop into plastic bag in a small freezing compartment. When full, bag is removed for pick-up and replaced with new bag.	Freezing prevents decomposition, odors and handling of waste is much easier and more sanitary and acceptable.	Relatively expensive to buy, requires plasticized bags, and electricity. Power failure or defrosting reactivates decomposition. Collection and ultimate disposal of bags must be organized and can create problems.	120V electricity	Electricity, no water	Approx. $400	Costs for 120 watt compressor and collection bags.
Incinerating	Wastes are incinerated in timed cycle after each use. Ash must be removed periodically. Models use electricity or gas.	No liquid waste generated and very little ash to dispose of. Reduces pollution.	Uses considerable energy. Some models require use of paper bowl liner with each use. Relatively complex mechanism. Must be vented.	120V or 220V (recommended) electricity, or optional 9.5 mm gas with 120V or 12V optional; 100 mm vent	Electricity or gas, no water	Approx. $650 - $1000	Depends on cost of energy. Uses approx. 0.1 cubic meters gas or 1 kW-h per use. Also, bowl liners and odour control catalyst.

TABLE 3 TOILET ALTERNATIVES (continued)

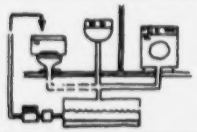
	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Composting (large)	Kitchen garbage and human wastes are digested by microorganisms, producing fertilizer.	End product, compost, can be used as fertilizer. Reduces pollution. No water, sewer or electrical hookups required. No moving parts. Little maintenance.	High initial cost for unit and installation. Unit is very large, requiring considerable basement space.	150 mm vent	none	$1500-$2500	None, some value created in fertilizer.
Composting (small)	Same as above, except compact and uses forced air circulation and heat to speed process.	No water or sewer hookups required. Unit is relatively small and can be installed in conventional washroom. End product, compost, can be used as fertilizer. Reduces pollution.	Expensive to buy and relatively complex to maintain and operate properly. Requires significant energy input and can not handle shock loading of organic and liquid wastes.	120V electricity 100 mm vent	Electricity, no water	$500-$1000	Power requirement of 1.2 to 8.75 kW-h per day for fan and heating element.
Synthetic fluid	System utilizes special chemical fluid or mineral oil as flushing medium. Waste materials settle out in holding tank and fluid is filtered and recycled to conventional toilet. Waste must be pumped out about once a year.	Utilizes conventional toilet and plumbing but no water. Can be used in conjunction with an incinerator to destroy concentrated wastes. Applicable for multiple units such as ramps or public washrooms.	High initial cost for unit and installation. Requires significant space and is relatively complex. Requires replacement of lost fluid and addition of odor control chemicals. Energy requirement for pumps and incinerator, if used, otherwise waste must be pumped out for disposal.	Connection to recycle system 9.5 mm water 75 mm waste Electricity for recycle system	Electricity, no water	$2500-$5000	Costs for replacement fluid, odor control chemical and power for electric motors.
Treatment systems (recycle) 	Recycle of treated and filtered toilet and/or other wastewater for toilet flushing. Sludge in tank must be pumped out every year or two.	Uses little or no fresh water. Some will accept wastewater from other fixtures.	High maintenance and capital cost. Requires filters, disinfectant, dye, pumps and electrical power.	Connection to treatment/recycle system 9.5 mm water 75 mm waste electricity for treatment and recycle system	Electricity, uses wastewater	$2500-$5000	Cost for disinfectant, dye, filters and electricity.
Urinals	Handle releases high velocity water injection syphoning liquid wastes through a trap.	Low volume flush models use very little water compared to conventional toilet. Uses conventional plumbing. Commonly used in public washrooms.	Relatively expensive addition to household washroom. Only handles liquid waste. Low consumer acceptance due to institutional and public image.	9.5 mm water 50 mm waste	4-15 litres/use	$75-$150	Depends on cost of water.

TABLE 4 BATHING ALTERNATIVES

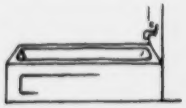
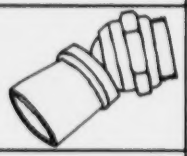
	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Bathtubs 	Vitreous china, fiberglass, or metal bathtub is filled with mixture of hot and cold water for bathing.	Facilitates personal hygiene and relaxation. Can be used without plumbing system and water can be reused. Level to which tub is filled need not be excessive, and water use is independent of duration of bath. Water can be left in tub to recover heat before discharge.	Uses relatively fixed volume of water per use. Large bathtubs with or without whirlpool spas, use large volumes of water. Most are not designed to conform to the shape of human body or insulated to reduce heat loss.	Varies from none to 9.5 mm H&C water and 38 mm waste.	Varies with size of tub and user habits. Approx. 150 litres/use.	Galvanized $30-$50 Vitreous china & fiberglass $80-$250	Depends on cost of water and energy for hot water heating.
Conventional shower heads	Blend of hot and cold water flows through a fitting with small openings to produce a water spray.	Convenient, quick method of body cleansing and rinsing. Water use can be regulated by time spent in shower.	Requires water and sewer plumbing and shower stall. Water consumption is high particularly with "massaging" type showerheads. Flow restrictors installed on some models may reduce the quality of shower to unfavorable as may low pressure systems.	9.5 mm H&C water and 38 mm waste	15-40 Lpm Typically 25 Lpm "massaging" as high as 55 Lpm. Normal shower duration is 5 mins.	Normal $5-$25 Typically $8. massaging $20-$50	Depends on costs; 5 minute shower every second day for family of four would use about 250 litres per day; ½ hot water.
Low flow shower heads 	Same as above, except water flow is restricted. Aerating types mix air with the water.	Same as above, except uses less water and energy to heat hot water for the same amount of time spent showering without sacrificing shower quality. Aerating types use less water. Most work well on low pressure systems by delivering a constant water flow regardless of pressure changes.	Generally a little more expensive than conventional shower heads and spray pattern is often narrower. Low flow may be noticeable by some, particularly for washing hair. Aerating type have non-adjustable sprays.	Same as above.	5-12 Lpm Typically 9 Lpm	$5-$25 Typically $10.	Same as above, except family of four would use about 90 litres per day, ½ hot water.
Flow controls	Small diameter orifice which restricts the flow of water. They are either an insert that slips into the shower water supply line or an independent fitting that is coupled onto the supply line ahead of the shower head.	Inexpensive retrofit method of reducing the flow of conventional shower heads. Can be homemade, consisting of a rubber washer with small diameter opening.	May reduce shower quality of some conventional showerheads.	Attaches, threads or inserts ahead of shower head.	8-12 Lpm Typically 10 Lpm	$1-$6.	Same as conventional, except consumption would be reduced to about 100 litres per day, ½ hot water.
Shut-off valves	A valve installed between the shower arm and the shower head to allow turning off of the water at the shower head without adjusting other controls. Some shower heads have shut-off valve built in.	Saves water by allowing user to conveniently shut off water at the showerhead while not under spray, lathering up, washing hair, etc. Some types have a small water flow while in off position which maintains the selected water temperature.	Water temperatures in riser stem or supply lines may change while valve is turned off. User may feel chilled when shower spray is turned off.	Attaches ahead of shower head.	Varies with flow rate and user habits.	$2-$5	Depends on flow rate and user habits. Approx. 0 to 50% savings.
Thermostatic mixing valves	Controls temperature changes from the hot and cold water supply lines by means of sensitive bi-metal spring. Two metals expand at different rates causing spring to move interior mechanism which controls the hot and cold supply lines, thus, maintaining a constant ratio of hot and cold water. Has two control knobs; one for temperature selection and the other controls the rate of water flow.	Provides constant pre-selected water temperature regardless of flow (pressure) or temperature changes in hot or cold supply lines. Increases user convenience, comfort and safety by reacting quickly to supply line temperature changes. One valve can control both shower and bath and/or other outlets.	Costs two to three times the price of conventional valves.	9.5 mm H&C water and supply line to shower head.	Not applicable, reduces waste.	Approx. $70.	None
Pressure balancing mixing valves	Designed specifically for showers, it compensates instantly for pressure changes in either the hot or cold water supply lines, usually due to the use of other fixtures, thus, maintaining the selected flow mixture resulting in a constant shower temperature.	Avoids discomfort and wasting of water by maintaining a consistent shower temperature.	Does not compensate for temperature changes from source unless accompanied by a pressure change. Costs about twice as much as conventional valves.	9.5 mm H&C water and supply line to showerhead.	Not applicable, reduces waste.	Approx. $50.	None

TABLE 4 BATHING ALTERNATIVES (continued)

	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Hand held showers	Shower head type fitting attached to a short hose, for hand held use. Can be permanently attached for use in shower stall or connected to end of faucet on sink basin.	Increases ability to get the water spray where it is desired with a minimum of inconvenience. Available with built in flow control and on-off valve. Can be permanently clipped to wall or attached to any faucet. Can be used to compliment conventional or low flow shower head, particularly for washing hair.	Potential danger of contamination by back-syphonage. If not clipped to wall, requires use of one hand. The wetting and rinsing operation may be inconvenient to some.	Faucet or shower outlet and 38 mm waste.	4-30 lpm greater for massage type.	$10-$30	Depends on costs and user habits. As low as 10 l/ shower.
Air assisted shower system	A small centrifugal air blower supplies air to a special showerhead where air and water are mixed to create a fine spray.	Very low water consumption while maintaining satisfactory cleansing. Can use in-line heater, therefore, no need for hot water supply line. Main economic advantage is amount of energy saved in water heating.	High capital and installation cost. Due to length of time required to drain water in hot water supply line, in-line heater, circulation of hot water or short distance to hot water tank is necessary. Requires enclosed shower stall. Separate blower required for each showerhead. Unsatisfactory shower for some.	9.5 mm H&C water 38 mm waste 120V electrical for blower.	2 lpm	$325	Depends on costs, family of four would use about 20 litres per day, ½ hot water. 25 kw/h (400 watts) per year for compressor.
Atomizer shower	Water of the desired temperature is delivered to an atomizing nozzle which produces a very fine spray (mist). The atomized water spray removes surface cells, dirt and soap.	Uses extremely little water. Existing designs are self-contained and require no water, sewer or power hookups and are portable.	Takes a long time to have a "complete shower." Drifting of spray if not within an enclosure. May require additional system for washing hair. Technology and plumbing not fully developed for conventional houses. Unsatisfactory shower for many.	None for self-contained models.	As low as 1 l/ shower	Approx. $5-$40	Negligible

TABLE 5 LAUNDRY ALTERNATIVES

	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Hand laundering	Beating or rubbing of articles together or rubbing on scrub-board in water filled tub or basin. Manual wringing of articles to remove excess water.	Complete user control over water quantity and temperature and number of articles laundered in same wash or rinse water. Does not require electrical hookup or household plumbing.	Highly labor intensive requiring considerable time, inconvenience and effort. Water use depends on size of tub and user habits.	None	Depends upon user.	Low to none.	None
Wringer washer	Agitator washing motion in user filled tub. User activates pump to drain wash or rinse water from tub. Laundered articles are manually fed through wringer to remove excess water.	User control over water quantity and temperature and number of wash loads laundered in same wash or rinse water. Can be moved to convenient storage location.	Capacity of tub varies with manufacturer. Requires time but not nearly as inconvenient or labor intensive as hand laundering. Possible to overfill or use too much water for varying wash load sizes. Wringer can be hazardous. Requires electrical hookup and storage space.	120v electrical and should be close to water supply and sewer drain.	Varies according to size of tub, manufacturers recommendations and number of rinses of wash and rinse water. Usually less than automatic washers.	$200 - $500	Depends on cost of water and power. Household of 5 would wash an average of 5 loads per week.
Top loading automatic washer	Top loading agitator motion for pre-selected wash/rinse/spin cycles. Wash and rinse water is automatically filled and drained with excess water spun from laundered articles.	Convenient automatic wash and spin dry cycles are labor saving. Other convenience features allow for water level and temperature selection. Some models offer a suds-saver attachment which will save water.	High range of water use among currently available models. Water level selection not possible on some models. Minimum wash load size may be high for small families. Temperature selection does not allow cold water rinsing on some models. Requires electrical and plumbing hookup and permanent space.	120V electrical and must be connected to water supply and sewer drain.	Total water use 140 - 280 litres Hot water only 60 - 87 litres	$450 - $700 average $500	Same as above
Low water use top loading automatic washer	Same as above.	Same as above except uses less water per cycle, promoting less use of detergents and other laundry additives.	Has slightly higher cost than average of other top load models. Maximum wash load sizes may be low for some families. Requires electrical and plumbing hookup and permanent space.	Same as above.	Total water use 111 - 148 litres Hot water only 27 - 53 litres	$525	Requires less water and laundry additives than above.
Front loading automatic washer	Front-loading tumble wash motion for pre-selected wash/rinse/spin cycles. Wash and rinse water is automatically filled and drained with excess water spun from laundered articles.	Lowest water use of currently available automatic washers. Has water level and temperature selection convenience features. Uses less detergent and other laundry additives and requires less operational energy than average of top load models.	Front loading door is not preferred by many consumers. Has slightly higher cost than average of top loading models. Maximum wash load size may be low for large families. Requires electrical and plumbing hookup and permanent space.	Same as above.	Total water use 114 litres. Hot water only 28 - 40 litres.	$650	Requires less water, operating power and laundry additives than above.

TABLE 6 MISCELLANEOUS WATER CONSERVATION ALTERNATIVES

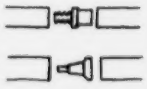
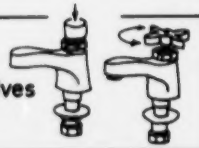
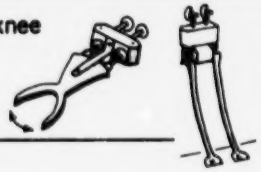
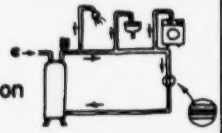
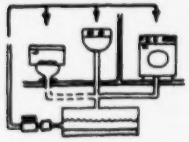
	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Conventional faucets	Water flow from supply line is controlled by rubber gasket which is turned down onto a seat. Gasket is connected to valve stem and operated by a handgrip. Available with single spigot or separate hot and cold faucets.	Valve controls water flow rate. Washerless valves with ceramic discs instead of rubber resist water and mechanical wear and operating temperatures up to 80°C.	High unrestricted flow rates. Wearing of rubber gasket type results in water loss due to leakage.	H&C water supply lines.	20 - 30 Lpm	$15 - $40 Washerless $40 - $50	Depends on cost of water and hot water heating.
Mixing faucets	Single faucet with one control handle that is used to adjust both flow rate and temperature of water.	Desired flow and temperature can be quickly selected and adjusted with only one hand, thereby reducing waste. Compact.	More expensive than conventional.	Same as above.	Reduces waste	$30 - $50	Same as above.
Spray faucets	Single faucet which delivers water in a spray, much like a shower head. Flow rate is preset and control knob is used for on/off operation and temperature selection.	Minimum pressure requirement of 13 kPa ideal for gravity tank systems. Compact and can use small diameter water supply and drain lines. Possible to use an in-line water heater eliminating need for hot water line.	Inconvenient for filling containers due to very low flow rate. Institutional image as they are commonly installed in public restrooms. Cost slightly more than comparable conventional faucets.	Same as above.	2 - 3.5 Lpm	$45	Same as above.
Thermostatic mixing valves	Temperature changes from the hot and cold water supply lines are controlled by means of sensitive bi-metal spring. Two metals expand at different rates causing spring to move interior mechanism which controls the hot and cold supply lines, thus, maintaining a constant ratio of hot and cold water. Has two control knobs; one for temperature selection and the other controls the rate of water flow.	Provides constant pre-selected water temperature irregardless of flow (pressure) or temperature changes in hot or cold supply lines. Increases user convenience, comfort and safety by reacting quickly to supply line temperature changes. One valve can control multiple water fixtures.	Expensive and generally used to supplement other faucets.	9.5mm H&C water and supply line to faucet.	Savings are up to 60% of that used by conventional faucets.	Approx. $70	None
Flow controls 	Reduce water flow rate by means of small diameter orifice in the supply lines ahead of fixtures or on end of spigot. Are either an insert or a threaded fitting. Most will compensate for pressure changes in water supply line to produce a constant flow rate.	Reduces flow rate where they are higher than desired or needed. Inexpensive and usually easily installed as retrofit. Some faucets have them built in. Available with various maximum flow rates.	May require cutting of existing water lines to install in-line type. Some users may feel flow rate is too low. Takes longer to fill and no water savings when filling containers such as a glass or bathtub.	Threads or inserts into supply line.	8 - 12 Lpm Typically 10 Lpm	$1 - $6	None
Aerators	Attaches to end of spigot and gives appearance of larger flow than actually present by breaking up flow and introducing air bubbles into the stream of water.	Restricts flow a little, however, main advantage is water use is reduced due to illusion of larger flow. Aerated flow feels gentle and greatly reduces splashing. New faucets generally equipped with an aerator but are inexpensive and easily installed on end of spigot of existing faucets. Some aerators have built in flow control increasing water conservation.	May not fit all old style faucets without an adaptor. Reduces flow rate slightly.	Threads onto end of faucet.	10-25 Lpm	$1 - $5	None
Self closing valves 	Spring loaded valve type, simply shuts off water supply immediately upon release. Timer valves are usually a single faucet with preset flow rate and temperature which automatically close due to accumulated water pressure.	Reduces waste since on only for time actually needed and ensures it will not be left on unattended or after use. Can be used with thermostatic mixing valve.	Do not operate unattended and therefore generally not practical for households. Separate spring loaded hot and cold faucets are inconvenient and warm water can only be obtained by mixing in bowl or container. Do not have temperature or flow rate selection.	H&C water supply lines.	Reduces waste	$30 - $40	Depends on cost of water and hot water heating.

TABLE 6 MISCELLANEOUS WATER CONSERVATION ALTERNATIVES (continued)

	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Foot or knee valves 	Faucet valve is activated by depressing a foot or knee lever and when released automatically returns to off position.	Reduces waste since water is on only when activated. Does not require hands to operate, therefore is convenient and sanitary.	Initial cost and modifications to existing equipment is expensive. Some do not allow temperature or flow rate selection. Must be attended to operate.	Mounting on floor or cabinet and controls to H&C water supply lines.	Reduces waste	$75 - $120	None
Pressure regulator	Adjustable spring is used to change pressure on a rubber diaphragm which in turn maintains the building water pressure at a preset value below the water main pressure.	Used where excessive water main pressures could burst fittings or cause excessive noise, vibration and leakage. Reduces water use and waste since maximum flow rate is reduced. Provides constant water pressure to building.	Lower pressure and therefore flow rate will increase time to obtain fixed volume of water.	Connects to building water supply line.	Saves water in all water outlets.	$30	None
Water pipe insulation	Insulation is placed or wrapped around water lines, usually hot water only, to reduce heat loss and help maintain temperature level of water in pipes.	Reduces heat loss and rate of cooling of water in pipes thus reducing wasting of water left standing in lines.	May be difficult, expensive and/or impractical to add to some existing water systems.	None	Approx. savings of 7.5 l/person d	$1.50 - $3 per meter	None
Water circulation 	Water pipes in the building or particular area are looped back to hot water tank and a small pump circulates water within the loop. Buildings with individual water systems only need a return line from each faucet to the cistern and a valve to allow draining. Faucets or other water outlets tap off of the loop. Usually only done for hot water pipes.	Eliminates need to waste cooled water standing in line between the heater and faucet before hot water is available. Provides hot water instantly since supply loop is maintained at hot water heater temperature. Circulation pump can be put on timer or thermostatic control to reduce heat loss and pump operating time.	Retrofitting existing systems may be impractical. Increased heat loss particularly for uninsulated pipes and where circulation pump is not on a timer. Circulation of water requires a pump.	Circulation pump (electricity) and return piping.	Reduces waste	$100 pump $25 plumbing	Nominal power for pump.
Recycle systems 	Household wastewater is collected and treated for reuse. Some systems only recycle greywater and may not recycle for drinking and cooking purposes. Treatment methods may include biological, chemical precipitation, filtration, carbon adsorption, reverse osmosis, distillation, disinfection and/or others.	Reduces total water requirements to zero or minimal. Building can be independent of water and sewer systems.	Very high capital and operating cost. Complex and high technology beyond most householders capabilities to maintain. Recycle of wastewater, except for toilet flushing, is a health hazard and is not aesthetically acceptable by many. Requires energy, chemicals and scheduled servicing by qualified personnel. Takes up space and may require alternative system for emergencies.	Electrical for treatment system and pumps, recycle piping and standby system.	Depends on system.	$2500 - $5000	Cost of chemicals and power requirement. Cost of recommended monthly servicing. Cost for fresh and makeup water.

consumer costs, particularly when there is a large reduction in water demand made possible by the concurrent use of a number of devices. In this report, for simplicity, an economic analysis based on a fixed unit price has been used to present typical results. A low and a high rate for both piped and trucked systems was selected and an economic analysis for a household of four was performed for each water use category. The rate conditions selected were:

Condition 1	-	Piped water and sewer at \$0.10/1000 L
	-	Electricity at \$0.05/kw•h
Condition 2	-	Piped water and sewer at \$1/1000 L
	-	Electricity at \$0.20/kW•h
Condition 3	-	Trucked water and sewer at \$10/1000 L
	-	Electricity at \$0.05/kW•h
Condition 4	-	Trucked water and sewer at \$20/1000 L
	-	Electricity at \$0.20/kW•h

The cost-effectiveness analysis was carried out for both a retrofit and new installation situation. The present value analysis includes all costs as if one agency or the consumer were paying for the total costs associated with water use and water conservation devices. Since money has a time value, a discount rate of 10% was used to convert future costs to an equivalent present value in order to equitably compare alternatives. Alternatives should be considered over a common life expectancy but in many cases the actual life is unknown and many fixtures are replaced before they actually fail. An economic life of 10 years is generally used in the calculations with rates and costs as of January, 1979.

6.1 Toilet Alternatives

Toilets use more water than any other fixture within the home. Conventional toilets, which typically use 20 L/flush, can be easily modified by the homeowner to reduce water consumption during flushing. Toilet modification devices range from simple homemade devices, such as weights or plastic bottle inserts, to inexpensive manufactured dams or dual flush attachments. A more expensive modification, applicable with the constant water pressures achieved on piped systems, is the replacement of the reservoir tank with a smaller sealed tank which is pressurized by the water supply.

There are a number of low water use toilets available. The lowest water use of the flush tank toilets are the European models. These toilets operate on the same

principle as conventional North American models, but flush in a shorter time period so that the velocities of discharged wastewater in the fixture drains is not appreciably different. This is illustrated in Figure 2, from a study by Konen and DeYoung (1975).

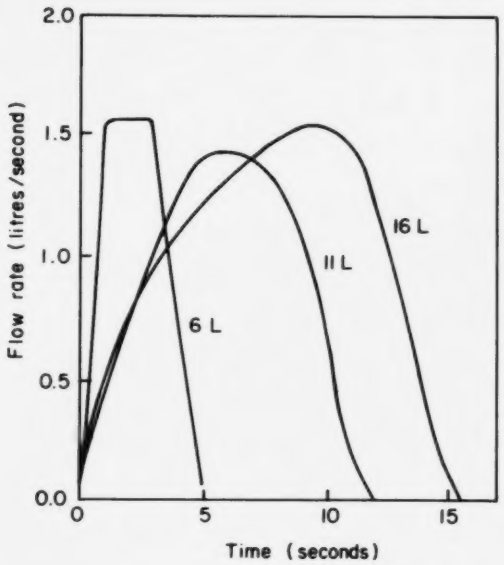


FIGURE 2 FLOW CHARACTERISTICS FOR 6, 11 AND 16 LITRES PER FLUSH TOILETS

The lowest water using toilets are the recirculating models. These toilet units require an initial charge of water and chemicals or other additives. Also available are a number of toilets which do not require any water. It is important to note that not all toilets are applicable or appropriate to every situation. For example, a mechanical seal toilet must be located directly over a receiving tank, and a three-litre flush European toilet should only discharge into a holding tank less than 25 m away through a 100-mm sewer line with a minimum slope of 3%. Other alternatives, including some reuse systems, are beyond the operating capabilities of most individuals and present severe maintenance difficulties, particularly when located in isolated communities.

Table 7 summarizes the capital and installed costs and operating requirements for 25 toilet alternatives. General present value equations for both the retrofit and new installation situations are also presented and they are used to calculate the present value of each alternative for a typical household of four for the retrofit case. For convenient comparison, the alternatives are ranked in order of increasing present value. In most

TABLE 7 INITIAL AND OPERATING COSTS AND ECONOMIC ANALYSIS OF TOILET ALTERNATIVES

ALTERNATIVES Code	Description	INITIAL COSTS Capital $	Installed (1) Retrofit[1] $	Installed (1) New[2] $	OPERATING REQUIREMENTS Water (L)	OPERATING REQUIREMENTS Others	PRESENT VALUE EQUATIONS[3]
1	Conventional	100	0[1]	250	20		1 + 122.9 R_w·U
1a	- Plastic Bottle	0	0	250	18		1 + 110.6 R_w·U
1b	- Weight	2	12	262	16		1 + 86.0 R_w·U
1c	- Dual Flush	4	14	264	14		1 + 86.0 R_w·U
1d	- Dam	8	18	268	13		1 + 79.9 R_w·U
1e	- Replacement Tank	90	140	360	10		1 + 61.4 R_w·U
2	Shallow Trap	115	145	265	13.5		1 + 82.9 R_w·U
2a	- Dual Flush	119	159	279	9.5		1 + 58.6 R_w·U
3	European 9L				9		1 + 55.3 R_w·U
4	European 6L	180	280	330	6		1 + 37.0 R_w·U
5	European 3L	225	325	375	3		1 + 18.4 R_w·U
6	British Dual Flush				6.6		1 + 40.6 R_w·U
7	Flush Valve	150	225	300	12.5		1 + 76.8 R_w·U
8	Air Pressure	1050	1150	1300	2	2 W/use[4]	1 + 12.3 R_w·U
9	Vacuum	1500	2000	2000	1.5	[4]	1 + 9.21 R_w·U
10	Mechanical Seal	90	150	270	0.5		1 + 3.07 R_w·U
10a	- Holding Tank	225	450	575	0.5		1 + 3.07 R_w·U
11	Marine	300	400	500	1	[4][5]	1 + 6.14 R_w·U
12	Recirculating	300	400	500	0.2	$0.004/use	1 + (1.22 R_w + 0.025)U
13	Packing	750	825	800	0	[6]	1 + 12 P
14	Freezing	400	475	450	0	[6] [7]	1 + 12 P
15	Incinerating	750	900	850	0	1.2 kWh/use	1 + 7.37 R_e·U
16	Compost (large)[7]	2300	3000	2750	0		1 + 0
17	Compost (small)	750	950	900	0	5 kWh/day	1 + 11200. R_e
18	Synthetic Fluid	2750	3500	3250	0	$75/year[8]	1 + 460 + M
19	Recycle - greywater	2750	3500	3250	0	$75/year[8]	1 + 460 + M
19a	Recycle - to toilet[9a]	1250	2000	1750	0	$25/year[8]	1 + 150 + M

PRESENT VALUE FOR RETROFIT[3]

	Piped Systems				Trucked Systems			
R_w =	$0.10/1000 L		$1/1000 L		$10/1000 L		$20/1000 L	
R_e =	$0.05/kWh		$0.20/kWh		$0.05/kWh		$0.20/kWh	
U =	5840		5840		5840		5840	
R_w·U =	584		5.84		58.4		116.8	
Rank	Alt	PV($)	Alt.	PV($)	Alt.	PV($)	Alt.	PV($)
1st	1b	62	1d	485	10	329	10	509
2nd	1c	64	4	496	12	618	12	690
3rd	1a	65	1e	499	10a	629	10a	809
4th	1d	65	2a	500	11	759	11	1117
5	1	72	1b	514	5	1400	19a	2150
6	1e	176	1c	516	17	1510	5	2474
7	2	193	12	553	8	1868	8	2587
8	2a	193	2	629	19a	2150	14	2635
9	7	270	1a	646	6	2441	13	2985
10	6	302	7	674	9	2538	16	3000
11	12	547	1	718	14	2635	9	3076
12	8	1157	8	1222	13	2985	17	3190
13	17	1510	9	2054	16	3000	18	3960
14	9	2005	19a	2150	15	3052	19	3960
15	19a	2150	14	2635	2a	3570	4	4602
16	14	2635	13	2985	1c	3726	2a	6980
17	13	2985	16	3000	18	3960	1e	7312
18	16	3000	17	3190	19	3960	7	9195
19	15	3052	18	3960	1d	4684	14	9350
20	18	3960	19	3960	7	4710	15	9508
21	19	3960	15	9508	2	4986	2	9828
22					1b	5034	1b	10056
23					1c	5036	1c	10058
24					1a	6460	1a	12918
25					1	7177	1	14354

NOTES:

(1) Assume that a conventional toilet is presently installed, therefore it must be removed, where necessary, and it has no salvage value.

(2) Includes all power and plumbing hook-ups.

(3) Assume a discount rate of 10% and an economic life of 10 years, therefore the Present Value Factor is 6.144.

(4) Power requirements are not a significant cost.

(5) Chemicals.

(6) Liners, electricity and pick-up.

(7) Electric models.

(8) Does not include qualified inspection and maintenance.

(9) Homemade system with water conserving toilet.

(10) Equivalent to a household of 4 with 4 toilet uses per capita per day.

WHERE:

I = Installed initial cost (Retrofit or New)

R_w = Rate for water and sewer service ($/L)

R_e = Rate for electricity ($/kWh)

U = Number of uses per year

P = Pick-ups per year

M = Present value of annual maintenance

PV = Present Value

Alt. = Alternative

cases, the present value is a function of the water and sewer rate (R_w) times the number of toilet uses per year (U). The results are plotted in Figure 3 for the retrofit situation and in Figure 4 for the new installation situation. These figures are valid for all values of $R_w \cdot U$; therefore, the present values of each alternative and the lowest cost alternative can easily be determined. To present $R_w \cdot U$ values applicable for both the piped and trucked systems on the same graph the scale was expanded in the zero to ten range. Since the choices are relatively clear, the scale does not go past a value of 70. To keep the scale large and reduce clutter not all of the alternatives are included. Notably, the high cost non-water using alternatives are excluded.

For the piped system retrofit situation, the conventional toilet modification devices are economical and should be installed in all toilets. At high water and sewer rates and/or high usage, the replacement of conventional toilets should be seriously considered. For the piped system new installation situation, it can be seen that a conventional toilet should only be installed for $R_w \cdot U$ values less than 0.5. At $R_w \cdot U$ values between 0.5 and 2.5 a shallow-trap toilet with or without a dual flush device or a conventional toilet with one of the simple conventional toilet modifications should be installed. For $R_w \cdot U$ values greater than 2.5, which is only 6.8 uses per day at \$1/1000 L, the European six-litre toilet should be installed although at higher rates and/or uses the recirculating toilet is slightly more economical.

The trucked system retrofit situation analysis shows that conventional toilets, even with any of the modifications, are very uneconomical and therefore could be replaced immediately with a savings. The mechanical seal toilet is always the lowest cost retrofit alternative; however, it can only be used if located directly over a holding tank, which would be uncommon for a retrofit situation. The lowest cost tank flush toilet is the European three-litre. It has a cost two to three times that of the recirculating toilet but some people will consider it to be the most aesthetic of the alternatives with reasonably low present worth values. The small compost toilet is only economically attractive where electricity rates are low, less than \$0.05/kW•h, and water and sewer rates are very high. The economics of the new installation situation for the trucked system are similar to the retrofit situation. It can be seen that, wherever possible, a straight drop mechanical seal toilet is the least cost alternative, but if installation is not possible or practical then a recirculating toilet should be installed. The most economic tank flush toilet considered is

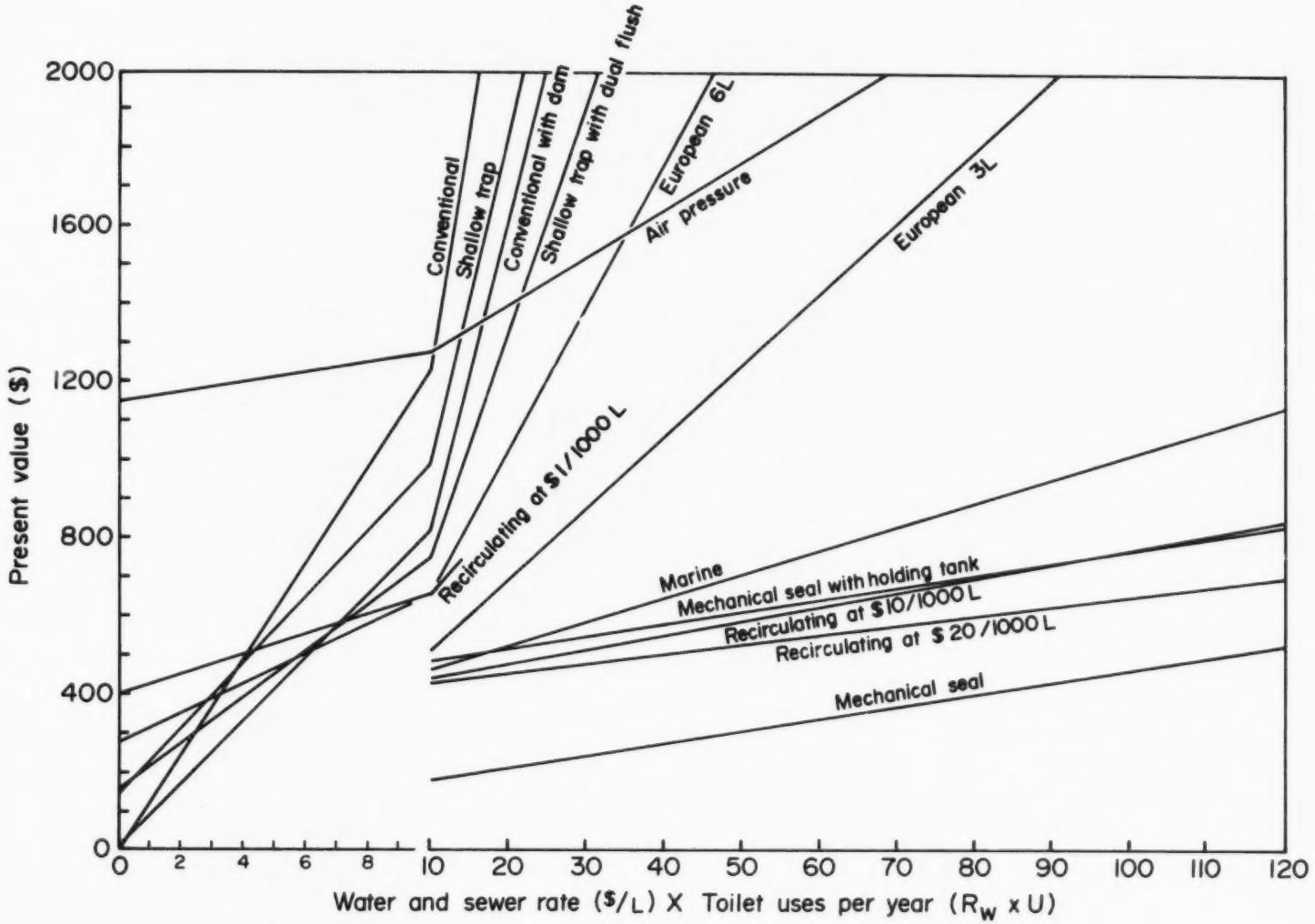


FIGURE 3 PRESENT VALUE OF TOILET ALTERNATIVES FOR RETROFIT SITUATION

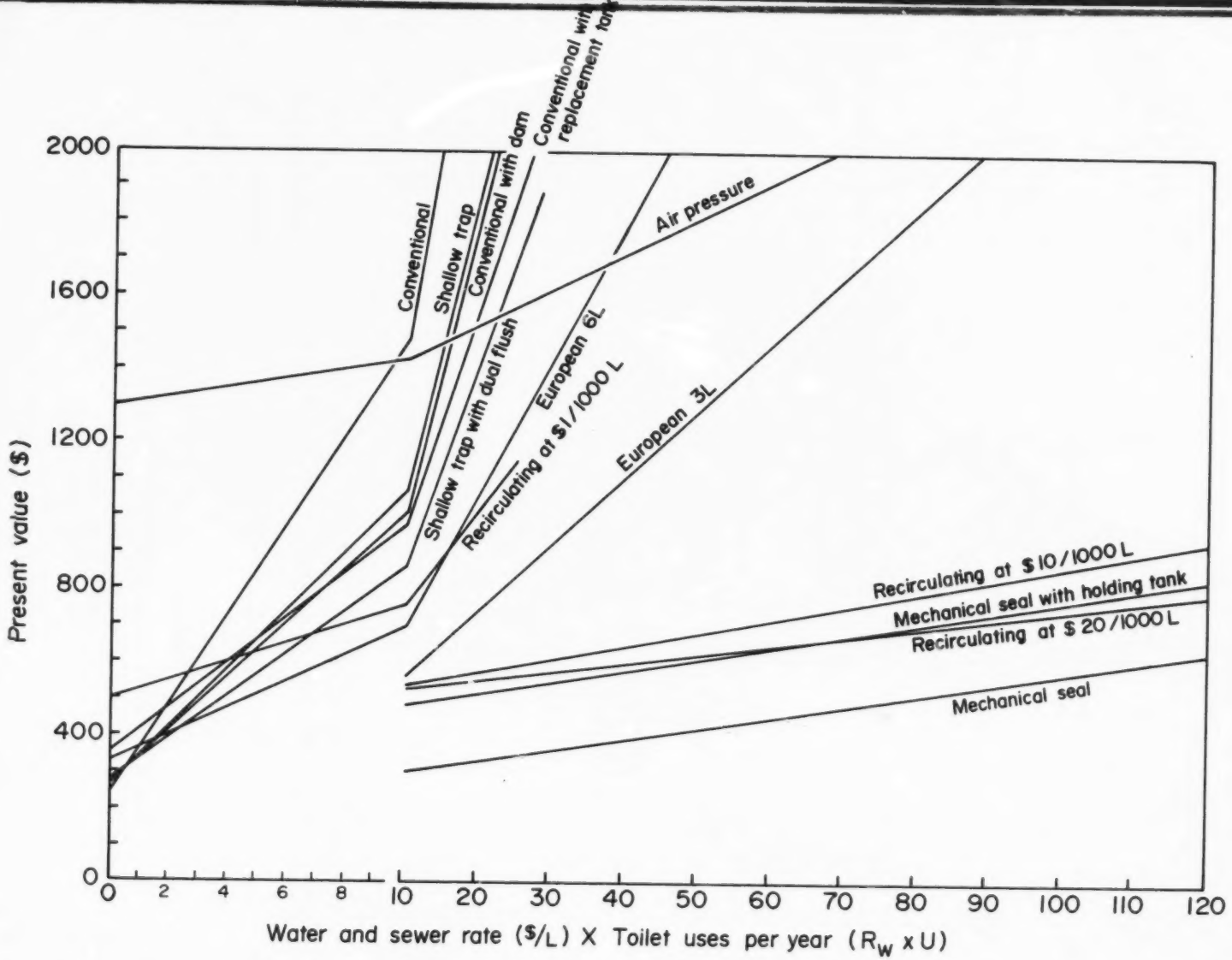


FIGURE 4 PRESENT VALUE OF TOILET ALTERNATIVES FOR NEW INSTALLATION SITUATION

the European three-litre unit, but even it has a present value which is about double that of the recirculating toilet.

6.2 Bathing Alternatives

Depending on the habits of the user, showers will usually consume less water than tub bathing, particularly if an inexpensive flow-restricting insert or specially designed low-flow showerhead is installed. Many low-flow showerheads will give a satisfactory or even superior shower while saving a considerable volume of water and energy required for hot water heating. Specialty shower units or systems that use very little water are available. Several add-on shower devices are available which will save water and some increase user convenience, comfort and safety.

Based on existing consumption data, a family of four on a piped system would bathe a total of approximately 630 times per year or approximately three times per week per person. Because not all of this usage would be for showering and the frequency is highly variable, and unknown for houses on trucked systems, it is useful to know the number of uses per year at which a particular alternative becomes economical. The average costs per bath for the various bathing alternatives at four unit rate conditions are presented in Table 8. It was assumed that a shower takes five minutes and the bathing water is heated 35°C to a temperature of 40°C. The same values were used for low-flow shower heads because there is no evidence to indicate that these would be significantly different. The cost per bath for electrical heating of hot water was calculated from:

$$\text{Cost/bath} = \text{Water Use/Bath} \left[(\text{Cost of water} + (0.041 \times \text{Cost of electricity})\right].$$

Over a 10-year period at a discount rate of 10%, the present value factor (PVF) is 6.144 and the present value of each alternative with an installed cost of I and U uses per year is:

$$\text{Present Value} = I + (U \times PVF \times \text{Cost/Bath})$$

From Table 8 it can be seen that a normal tub bath of 150 L will use a little more water than a conventional shower of 125 L but far more than a low-flow shower at 45 L per shower. Even if this was reduced by the use of smaller, insulated and better designed tubs, and through reformed user habits, it is unlikely this could be reduced below that of a low-flow shower. Tub bathing is generally less economical and will be an expensive luxury where water and energy costs are high.

TABLE 8 AVERAGE COST PER BATH

	PIPED SYSTEMS		TRUCKED SYSTEMS	
	Condition 1	Condition 2	Condition 3	Condition 4
Unit Cost of Water	$0.10/1000 L	$1/1000 L	$10/1000 L	$20/1000 L
Unit Cost of Electricity	$0.05/kW·h	$0.20/kW·h	$0.05/kW·h	$0.20/kW·h
Alternatives	$	$	$	$
Tub Bath - 150 L				
Water	0.015	0.150	1.500	3.000
Heating	0.300	1.230	0.300	1.230
Total Cost	0.315	1.380	1.800	4.230
Conventional Shower - 125 L				
Water	0.013	0.125	1.250	2.500
Heating	0.256	1.025	0.256	1.025
Total Cost	0.269	1.150	1.506	3.525
Low Flow Shower - 45 L				
Water	0.005	0.045	0.450	0.900
Heating	0.092	0.369	0.092	0.369
Total Cost	0.097	0.414	0.542	1.269
Air Assisted Shower - 10 L				
Water	0.001	0.010	0.100	0.200
Heating	0.021	0.082	0.021	0.082
Total Cost	0.022	0.092	0.121	0.282
Hand-held Shower - 10 L				
Water	0.001	0.010	0.100	0.200
Heating	0.021	0.082	0.021	0.082
Total Cost	0.022	0.092	0.121	0.282

For all practical conditions, it is economical to modify an existing shower head with a flow restrictor or to install a low-flow shower head. For example, at the low piped rates of $0.10/1000 L and $0.05/kW•h the installation of a low-flow shower head saves $0.17/use over an existing conventional shower head. If the installed cost is $18, it pays for itself after 105 uses, which is equivalent to only 17 uses per year. At 500 uses per year, the present value of the savings would be $500. At higher electrical rates and for trucked systems, the savings are even greater. For example, at the low trucked rates of $10/1000 L and $0.05/kW•h, the savings are $0.96 per five-minute shower. Therefore, retrofitting a low-flow shower head becomes economical after only 20 uses and the present value of the savings at 250 uses per year is $1460. The initial cost of the shower head is insignificant and, therefore, the primary concern in choosing one is user satisfaction.

An inexpensive on/off control for the shower head, if used properly, can quickly pay for itself and is usually worth obtaining for both piped and trucked systems. A hand-held shower unit complements the low-flow shower head and should be installed to make the system more attractive and to facilitate even lower water use. The same applies to the thermostatic and pressure balancing mixing valves which may not be strictly economical on their own.

The air-assisted shower system is considerably more expensive than the hand-held shower head. This is particularly true for the retrofit situation and in some buildings this system may be impractical to install. This system must include a shower stall, thermostatic mixing valve and instant hot water. If this system could be installed for $700 it would be more economical than a low-flow shower head providing the number of uses per year is greater than 230 at the low trucked rates of $10/1000 L and $0.05/kW•h and greater than 100 at the high trucked rates of $20/1000 L and $0.20/kW•h. For most households this shower system would be uneconomical or at least unattractive.

With a self-closing hand-held shower system bathing can be achieved with as little as 10 L per shower, which is the same as a five-minute shower with an air-assisted shower system. This system requires a shower stall, thermostatic mixing valve and instant hot water. At 250 uses per year, the present value of the benefits with such a system, compared to a low flow shower head, are $950 and $1600 at the low and high trucked rates, respectively. The capital cost for this system will vary, but it will be less expensive and easier to install than an air-assisted shower system and, therefore, more economically attractive. It can be used as a supplement for a low-flow shower head or as the primary system where water is limited or very expensive. However, the use of a hand-held shower system will require a significant change in bathing style, which would be unattractive to many people. A study of this system by Schatzberg (1975) showed that user acceptance was improved considerably with use.

6.3 Laundry Alternatives

Hand laundering uses potentially the least amount of water, but considerable user time and effort is required. Wringer washers are versatile and reuse of the water is easily done but they have been largely superseded by the more convenient automatic washing machines. Numerous top loading automatic washers are available, some of which use considerably less water than others. Front load washers utilize a more efficient tumble action and use the least volume of water of any of the automatic washers. However, they are more expensive and consumer acceptance to date has been poor.

The initial and operating costs and an economic analysis of automatic laundry machine alternatives for the retrofit and new installation situations are presented in Table 9. Equations for the present value of each alternative in terms of the water and electricity rates and number of uses per year are given. To illustrate the economics for retrofit and new installations, the present values for each alternative for two piped and two trucked water and electricity rates, and for 251 and 106 wash loads per year are presented. These frequencies were based on the number of washing loads per year expected for a piped and trucked household of four, respectively, if 14.6% of the total household water was used for laundering with a conventional top load automatic washer.

The analysis indicated that, for the piped retrofit situation, it is only economical to replace an existing conventional washer with a front load washer when usage as well as water and electricity rates are very high. For example, at the piped system rates of \$0.10/1000 L and \$0.05/kW•h the break-even point is at 610 uses per year, and at the higher rates of \$1/1000 L and \$0.10/kW•h the break-even point is 270 uses per year. For most households on piped systems there are potential savings to be realized by installing a front load washer in new buildings or when an existing machine is to be replaced. At the lower rates for the new installation situation the break-even point is 120 uses per year and at the higher rates the break-even point is only 50 uses per year.

For the trucked system retrofit situation it is economical to replace an existing conventional washer with a front load model for most households. For example, at the low rates of \$10/1000 L and \$0.05/kW•h the break-even point is 140 uses per year and at the higher rates of \$20/1000 L and \$0.20/kW•h the break-even point is 65 uses per year. Apartment buildings or large households could substantially benefit from the retrofit but small families or couples would only obtain marginal savings from a retrofit unless the existing machine had some salvage value. For new installations it is practically always more economical to install a front load washer. The break-even point is 25 and 15 uses per year for the low and high trucked systems rates, respectively.

6.4 Dishwashing, Drinking and Cooking

Dishwashing accounts for most of the water used in the kitchen. Handwashing dishes can be done with very little water but may entail some inconvenience and extra effort. If an automatic dishwasher is used and it is always loaded to capacity for each full cycle of operation, water use will be comparable to hand-washing dishes in a full sink and rinsing dishes under a free flowing stream of water. In-sink food waste disposal units are a modern convenience which, if judiciously used, will not significantly increase household

TABLE 9 INITIAL AND OPERATING COSTS AND ECONOMIC ANALYSIS OF LAUNDRY ALTERNATIVES

ALTERNATIVE		INITIAL COSTS				OPERATING REQUIREMENTS	PRESENT VALUE EQUATIONS [3,4]
Code	Description	Capital ($)	Installed (1) Retrofit[1] ($)	Installed (1) New[2] ($)	Total Water (L/Use)	Others[3]	
1	Conventional Top Load	550	0[1]	700	190.8	Hot Water[5] = 61.2 L Heating[6] = 3.67 kW·h Electricity[7] = 0.23 kW·h Detergent = 300 mL Bleach = 225 mL	I+ PVF(0.19R_W + 3.90R_E + 0.20)U
2	Low Use Top Load	625	700	775	139.1	Hot Water = 39.8 L Heating = 2.31 kW·h Electricity = 0.23 kW·h Detergent = 300 mL Bleach = 225 mL	I+ PVF(0.14R_W + 2.54R_E + 0.20)U
3	Low Use Front Load	700	775	850	119.2	Hot Water = 29.8 L Heating = 1.73 kW·h Electricity = 0.18 kW·h Detergent = 150 mL Bleach = 113 mL	I+ PVF(0.12R_W + 1.91R_E + 0.10)U

PRESENT VALUE AND RANKING OF ALTERNATIVES[3,4]									
		Piped Systems				Trucked Systems			
	R_W =	$0.10/1000 L		$1/1000 L		$10/1000 L		$20/1000 L	
	R_E =	$0.05/kW·h		$0.20/kW·h		$0.05/kW·h		$0.20/kW·h	
	Rank	Alt.	PV($)	Alt.	PV($)	Alt.	PV($)	Alt.	PV($)
RETROFIT INSTALATIONS									
U = 251 [8]	1st	1	640	3	1700	1	2915	3	5195
	2nd	3	1095	1	1805	2	3350	2	6080
	3rd	2	1225	2	2005	1	3550	1	7395
U = 106 [9]	1st	1	270	1	765	1	1500	3	2640
	2nd	3	910	3	1165	3	1680	2	2975
	3rd	2	920	2	1250	2	1820	1	3125
NEW INSTALATIONS									
U = 251	1st	3	1170	3	1775	3	2990	3	5270
	2nd	2	1300	2	2080	2	3425	2	6155
	3rd	1	1340	1	2505	1	4250	1	8095
U = 106	1st	1	970	3	1240	3	1755	3	2715
	2nd	3	985	2	1425	2	1895	2	3050
	3rd	2	995	1	1465	1	2200	1	3825

NOTES:

(1) Assume that a Conventional Top Load washer is presently installed therefore it must be removed, where necessary, and it has no salvage value

(2) Includes all power and plumbing hookups

(3) Does not include Maintenance costs which are assumed equal for all washers.

(4) Assume a discount rate of 10% and an economic life of 10 years, therefore the Present Value Factor is 6.144

(5) Assume hot water heating by electricity.

(7) To operate washer

(8) If a typical household of 4 on a piped system uses 225 L/person·d x 4 = 900 L/d and 14.6% of that is for laundry, then a typical household would do approximately 251 wash loads per year.

(9) If a typical household of 4 on a fully trucked system uses 95 L/person·d x 4 = 380 L/d and 14.6% of that is for laundry, then a typical household would do approximately 106 wash loads per year.

WHERE:

I = Installed initial cost (Retrofit or New)

R_W = Rate for water and sewer service ($/1000 L)

R_E = Rate for electricity

U = Number of uses per year

PVF = Present Value Factor

PV = Present Value

Alt. = Alternative

water use. Other kitchen operations such as drinking and cooking use relatively fixed and small volumes of water. Reductions in the wasting of water can be achieved by adjusting user habits, such as by keeping a container of cold water in the refrigerator and not running taps needlessly.

6.5 Miscellaneous Water Conservation Alternatives

There are a number of faucets and faucet attachments that reduce the amount of water flow and wastage compared to conventional faucets. Water flow reduction at faucets has the added benefit of energy savings since approximately 50% to 75% of the flow is heated water (Nelson, 1977). Mixing faucets, which have a single control handle that adjusts both the flow rate and the water temperature, will reduce wasting of water. There is a special single-handle faucet available which produces a water spray with approximately 10% of the flow rate of conventional faucets. While this low flow rate greatly reduces water use when washing under a free flowing faucet, the major drawback is that spray faucets are inconvenient for filling basins, sinks or other containers. Spring-loaded and self-closing faucets reduce waste since they do not operate when unattended, but they are inconvenient for household use. Thermostatically-controlled mixing valves can be used to maintain constant pressure and a pre-selected water temperature at faucets.

When the flow rate of a faucet is higher than desired or needed, a flow control can be installed in the water lines ahead of the fixture or added to the end of the spigot. These devices restrict water flow by means of a small-diameter orifice and are either an insert or a threaded fitting. The operation and the flow rate characteristics of a pressure compensating flow control device is shown in Figure 5.

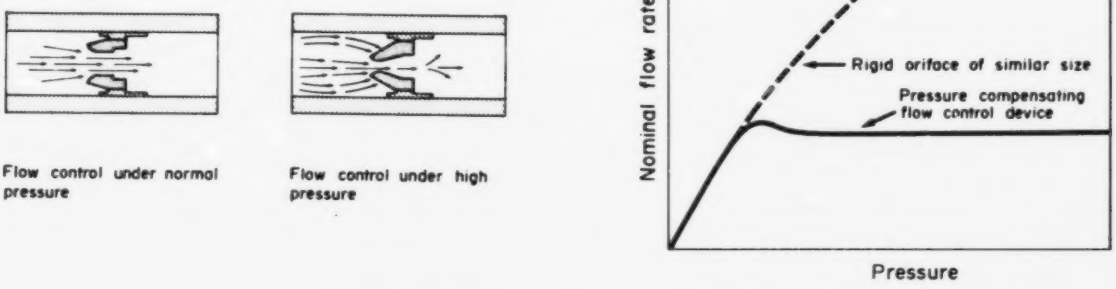

Flow control under normal pressure
Flow control under high pressure
Nominal flow rate
Rigid orifice of similar size
Pressure compensating flow control device
Pressure

FIGURE 5 OPERATION AND FLOW RATE CHARACTERISTICS OF A PRESSURE-COMPENSATING FLOW CONTROL DEVICE

Aerators will also act as a flow control since they reduce the amount of water that can flow out of a faucet. Aerators are easily attached to the end of the spigot and they give the appearance of a larger flow than is actually present by breaking up the flow and introducing air bubbles into the stream of water. There are water conserving aerators available with a built-in flow control. Flow control and/or aerators are desirable because of their low cost, water and energy savings and convenience.

Pressure regulators are installed where excessive water main pressures could burst fittings or cause excessive wasting of water at faucets, noise, vibrations and leakage. A pressure reduction in the supply line will reduce the rate of water flow through the fixtures and water use will be reduced for a free flowing stream of water, such as a shower. However, the lower pressure and flow rate will increase the time required to obtain a fixed volume of water. Where existing water pressures are excessive, pressure regulators will be convenient and economical.

Insulation of hot water lines reduces heat loss and helps maintain the temperature level of the water in the pipes. Thus, wasting of cooled water left standing in the lines will be reduced. A "rough" savings estimate for hot water pipe insulation of 7.5 L/person•d or approximately 3% of total water use was given by Nelson (1977). While the cost of insulating hot water lines will vary, in most cases it will be economical for houses on trucked systems and will be desirable for houses on a piped system.

Another method used to reduce wasting of cooled water in the line between the hot water heater and the faucet is hot water circulation. With this system, the hot water pipes in a building or particular area are looped back to the hot water tank and a small pump circulates water within the loop. There is an alternate method which can be used in buildings with individual water systems that does not require a circulation pump. This method requires a return line from each faucet to the cistern and a drain valve located on that line at each faucet. When hot water is received at the faucet, the drain valve is closed and hot water can be obtained from the faucet. The reduction in water use with either the circulating or return hot water system will be at least that of insulating the hot water pipes, 3% of total household water use. The economic benefits will also be similar; however, either system would only be economical for houses served by a trucked system. Because the hot water return system is simpler it appears to be the best choice; however, some development work may be necessary to make it convenient and acceptable to the users.

6.6 Wastewater Reuse

The reuse of water can significantly reduce water demands and some technology can practically eliminate the need for a water supply and sewage collection system. In some situations, the autonomous aspect may be either necessary or at least very attractive, while in others, the economic benefits of reduced water use and energy requirements may be prominent. The potential pollution and health hazards of the effluent from buildings with reuse remains the same unless the recycle system incorporates some form of treatment and sludge management. These latter systems can reduce or practically eliminate pollution of the local environment. Although the benefits of reuse are attractive, the high costs, technical problems and public acceptance have generally limited the application of reuse to demonstration projects and specific aerospace and military projects.

Treatment systems for reuse depend very much upon the type of wastewater and the intended use. To minimize the treatment requirements, water can sometimes be cascaded in a sequence of uses which require progressively lower quality water. An example of this is the reuse of washwater for toilet flushing but in many cases it is impractical to have multi-treatment systems and the single treatment system used must provide a water quality that is adequate for the most stringent use planned.

Unless complete autonomy or "zero" pollution is a prerequisite, limited or selective recycle appears to be more practical and attractive. Smith (1973) analyzed the economics of recycling compared to water conservation and concluded that "a change in equipment and habit could eliminate the need for water recycling, except for some local recycling within a particular water use function itself, and this seems the most economical alternative". Unfortunately, few other authors have looked at water conservation versus, or in conjunction with, reuse to minimize the capital cost and operating requirements. For example, the most often proposed application of reuse is for toilet flushing; however, a number of low water use toilet alternatives can provide nearly the same flow reduction benefits with simpler technology. The small water requirements of low-water use toilets would render reuse uneconomical unless perhaps a toilet was selected and the reuse system designed such that treatment before reuse was not required. There are also toilets available that do not require water and toilets that produce a dry stable residue for disposal, including incinerating and composting toilets. As another example of conservation versus reuse, the use of a hand-held shower unit or an air-assisted shower system can reduce bathing water requirements by over 90% compared

to a conventional shower and these water conservation alternatives may be more acceptable and are certainly less complex than recycling.

The remaining practical use of renovated greywater is for laundry. Front load washing machines would reduce water requirements by about 40% compared to a conventional top load washer. If the water conservation measures previously mentioned were implemented this would make laundry the major household user of water. Some authors have suggested the use of ultrasonics to reduce the laundry water requirements. If this technology is unavailable, it appears that the most practical and economical application for reuse is for laundering.

6.7 Community Systems

Water demand is dependent upon the type of utility system and its design as well as the plumbing within the buildings. Water demand and wastewater flows in piped systems can be reduced by a number of measures but the degree of reduction is very dependent on the characteristics of the existing system. One method of reducing water consumption is to maintain the water main operating pressures at a minimum since high pressures result in wasting of water at uncontrolled faucets, for lawn watering and other outdoor uses, and from leaks. Another method is to limit the flow rate in the supply line to each building by installing an inexpensive constant flow device. The U.S. Environmental Protection Agency (1974) has emphasized the reduction in wastewater flows through the elimination or control of infiltration. This is more significant in older systems that may have breaks in the sewer lines and those that have been designed with non-watertight joints or appurtenances. Pressure or vacuum sewer systems do not require the large volumes of water that are necessary to transport wastewater in gravity sewer collection systems and, with either system, water use for toilets can be reduced drastically.

As an alternative to conventional utility systems for small unserviced communities, the Alaska Village Demonstration Project provided a central facility with laundry and showers as well as a safe water supply and integrated waste management system (Reid, 1977). Household water demand was only 5.5 L/person•d but significant health benefits were observed. Recycle of greywater for laundry and low water toilets was used to reduce water requirements at the central facility to 17 L/person•d. A central facility with or without reuse provides basic services and various water conservation alternatives can be easily incorporated to reduce water use. Where water supply is limited and the complete winter's supply must be stored, and/or where the unit cost of

water and sewerage service is high, a central facility should be considered to reduce demand and total community water use related costs. In some cases, the possibility for conservation and reuse may even dictate the installation of a central facility.

7 SUMMARY AND RECOMMENDATIONS

Water demand is influenced by many factors; in northern communities, the most significant of these are the plumbing and water-using appliances within the house and the type of utility system. Improvement of the levels of service and sanitation is still a goal in many northern communities. This objective can be aided through increased water availability and use, but it is important to ensure that water is used efficiently and economically. Subsidies, which are often extensive in the north, can distort demand and introduce inefficiencies. To minimize utility system costs, direct or indirect subsidies should only be applied to the quantities that will facilitate their intended goals, and demands over that quantity should be charged at the actual total cost to provide that service. The rate structure and marginal price should reflect the long-term cost of the utility system even though subsidies, administrative practicalities and technical difficulties will require some compromises with strict economic efficiency.

Water use can be significantly reduced by public education, and utility operators or agencies that wish to reduce water use should initiate a public information and education campaign. Knowledge of simple water conservation hints and an awareness of the benefits of water conservation devices can further reduce waste and conveniently increase the efficiency of water use. Plumbing codes that emphasize water conservation should be formulated so they could be easily adopted by interested government agencies, municipalities or those responsible for building design or utility systems.

The reduction in water demand and energy used for hot water heating will make various water conservation devices economical. Usually the decision involves selecting the most cost-effective of a number of alternatives. To demonstrate the economic selection methodology and typical results, an analysis was conducted for a four-person household. It was necessary to make a number of reasonable assumptions but where conditions are significantly different a site-specific analysis should be carried out. By selecting specific water, sewer and power rates that span the expected range of marginal costs, a cost-effectiveness analysis for both the retrofit and new installation cases was carried out. The results of the analysis are highlighted below and are summarized in Table 10. Some water conservation alternatives can be recommended for general application but, because of variable costs and uncertain benefits, other alternatives require individual assessment. The reductions in water use are based on the "normal" consumptions for a family of four in a house with full conventional plumbing and water-

TABLE 10 RECOMMENDED HOUSEHOLD WATER CONSERVATION STRATEGIES

● Recommended
↓
○ Preferred option

	Piped systems		Trucked systems	
	Retrofit installation	New installation	Retrofit installation	New installation
Toilet				
Dual flush or dam	●			
15 L or less per flush		●		
3 L or less per flush			●	●
Bathing				
Low flow shower head	●	●	●	●
Hand-held shower unit	○	○	○	◑
Temperature control valve				◑
Laundry				
Front load washer		○	◑	●
Miscellaneous				
Flow control aerator	●	●	●	●
Mixing faucet		◑	○	●
Temperature control valve				○
Pressure reducer	○	○		
Insulate hot water pipes	○	●	○	●
Circulating or return hot water				◑
Savings over conventional[1]				
Water (%)	28-38	31-55	50-67	60-74
Water (L/person·d)	63-84	70-124	47-63	57-70
Energy[2] (kW·h/person·d)	1.34-2.03	1.56-2.26	0.56-1.69	0.86-1.16

[1] Range of values depends on alternatives or devices used and bathing habits.

[2] For household hot water heating.

using appliances, which are 225 L/person•d for houses on a piped system and 95 L/person•d for houses on a trucked system. The water use breakdown in Figure 1 was assumed.

7.1 Piped Systems

The economic analysis for the retrofit case indicated that conventional toilets should be modified by the installation of a dual-flush mechanism or a dam insert to reduce the volume of water used per flush. A low-flow shower head should be installed, primarily because of the energy savings, and to complement it a hand-held shower unit may be a preferred option. All faucets should have a flow control aerator added to the spigot. If the water main pressure is excessive, a pressure reducer should be installed and, wherever practical, the exposed hot water pipes should be insulated. These toilet and shower modification recommendations should cost less than $25, can be easily installed by the homeowner and would reduce total household water demand by 28% to 38%. The high value would be realized where only showers rather than tub baths are used.

For new buildings or when an existing fixture is to be replaced, it is recommended that the toilet selected be one that uses 15 L or less per flush. A conventional toilet with one of the simple modifications is recommended at very low water rates, whereas at higher rates the European 6-L toilet is the most economically attractive alternative. A low-flow shower head is economical and an on/off switch and a hand-held shower unit are desirable optional equipment. Flow control aerators should be installed and when mixing faucets are not too expensive, their convenience and reduced water use make them desirable. Insulating the hot water pipes also improves convenience and is usually economical for a new building. If the water main pressure is excessive, a pressure reducer should be installed. These recommendations would entail an incremental capital cost over and above that of conventional plumbing fixture costs of approximately $25 to $115, depending upon the toilet selection. Household water use would then be reduced by 31% to 55%. The higher cost and reduction values pertain to the use of the European 6-L toilet and shower bathing.

7.2 Trucked Systems

Because of the high unit cost of water with trucked systems, the strategy outlined in Table 10 for the retrofit case recommends removing conventional toilets and installing units that use a maximum of 3 L per flush. If a mechanical seal toilet cannot be installed, the cost-effective alternative is a recirculating toilet. The only conventional

flush type toilet that should be considered is the European 3-L toilet. Tub-bathing is comparatively very expensive. A low-flow shower head is very economical and should be installed, and the installation and use of an on/off shower valve and a self-closing hand-held shower unit should be encouraged. Where utility rates are high and/or a large number of wash loads are done, retrofitting with a low water use front loading automatic washer will be economical. Mixing valves are a desirable option, but in any case, flow control aerators should be installed. Hot water pipes should be insulated where practical. The cost of these recommendations will vary with the options selected. If all of the options, including a front loading clothes washer, are installed, the capital cost would be $1,000 and the total water consumption would be reduced by approximately 55% to 67%. Without changing the laundry machine, the capital cost would be approximately $300 and the benefit would be a 50% to 55% reduction in total water use.

For a new installation even more drastic changes from conventional fixtures are economical. The toilet selected should use 3 L or less per flush and the alternatives, in order of increasing economic attractiveness, are the European 3-L, the recirculating, and the mechanical seal toilets. A low-flow shower head and a self-closing hand-held shower unit should be used and a temperature control valve can be installed to increase user convenience and reduce waste. A front loading clothes washer becomes quite attractive, particularly if there are a large number of wash loads per week. Mixing faucets with flow control aerators should be installed. Hot water pipes should be insulated and in most cases a hot water circulation or return system would economically increase user convenience. The incremental capital cost of these items above conventinal plumbing costs would be approximately $325 to $525. If the frequency of use and personal habits are unaffected, the installation of these devices will provide a reduction in trucked household water use by 60% to 74% and water requirements will be reduced to between 38 and 25 L/person•d.

In the previous analysis one of the assumptions made for trucked households was that the household water use distribution was similar to that for piped systems (Figure 1), even though the total water use is typically much lower than for piped houses. The same percent reduction in water use for each function was then applied to the trucked and piped systems. A more conservative estimate of the benefits of water conversation devices would be to assume the fixture usage rates obtained from piped household data. Typical daily per person rates would be approximately 4.5 toilet flushes, 0.43 baths and 0.17 launderings. If a recirculating toilet (0.2 L/flush), low-flow shower

head (45 L/bath), front load automatic clothes washer (119 L/load), and other miscellaneous devices were installed the total water use would be approximately 50 L/person•d. This value represents the lower limit of water demand in a house equipped with cost-effective water conservation plumbing fixtures and little conscious effort on the part of the householders to conserve water. This 47% reduction in water demand represents a total annual savings per household over conventional plumbing fixtures of approximately $650 at the low rates and $1300 at the high rates.

7.3 Public Buildings

For most public buildings such as schools, offices, hotels or laundraumats, the fixture usage rate will be higher than for a household; therefore, the recommendations in Table 10 would apply as a minimum. In addition to household options, self-closing faucets and low-flow showers with timers should be installed. Spray faucets for lavatories should also be considered, particularly where utility costs are high. Temperature control valves that control a number of faucets and a circulating hot water system are desirable and may be necessary with some faucets.

7.4 Critical Situations

Where utility costs are very high and/or where there is a limited water supply, severe steps may be necessary to reduce water requirements. The inherent lower water use and greater control available with a trucked system will probably rule out a conventional piped system, and perhaps even a non-gravity sewage collection system. Even in these situations, household reuse is not attractive when compared to water conservation. Households should use a mechanical seal or recirculating toilet. A self-closing hand-held shower unit is recommended for bathing; therefore, a hot water circulation or return system and a temperature control valve would be necessary. A spray faucet could be installed in lavatories and other locations should use mixing faucets equipped with flow control aerators. Along with a front loading clothes washer, these fixtures could reduce trucked household water demand by 78% which would be only 21 L/person•d compared to a normal demand of 95 L/person•d. If a central laundry were used, the household demand would be reduced to only 13 L/person•d. In some cases a central laundry with reuse may be economical but, due to the rather complex treatment technology that is necessary, this should be approached with some caution.

8 FURTHER STUDIES

Within this study a number of assumptions that have been made should be verified. In particular, the characteristics of water use within northern households served by trucked systems should be monitored.

The water conservation recommendations in this paper should be demonstrated in both retrofit and new installation situations for both piped and trucked systems. The objectives would be to survey user acceptability, monitor water use and determine the economics. Individual fixtures may be tested but houses completely equipped with water conservation technology should be demonstrated. Two categories of water conservation technology should be demonstrated and assessed. The first category consists of known and available technology such as the low-flow shower heads, flow-control aerators, conventional toilet modifications, and recirculating and European toilets. A second category of new or emerging technology should be demonstrated in more selective and controlled situations. These would include the self-closing hand-held shower units, return hot water systems and reuse at central laundry facilities.

The continued monitoring and development of water conservation technology to further increase user convenience and acceptance and to reduce capital and operating requirements should be encouraged and funded. Areas in which future technology could provide benefits include the development of very low or even non-water using dishwashing and laundry alternatives; simple greywater reuse systems for households and central laundries; and a reliable, aesthetic and compact compost toilet that does not require supplemental heating.

9 FINAL REMARKS

With prudent application and acceptance of water conservation methods and technology, the goal of improving the level of service and sanitation in many northern communities can be realized much more quickly than originally thought possible. The implementation of water conservation programs will significantly improve the economics of providing services and enable limited budgets to be stretched further. In addition, reduced household water requirements will influence the types of water and sewage systems which are cost-effective in northern communities. For example, the cost of trucked services is directly related to water consumption and reductions in demand will significantly influence their economic attractiveness.

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